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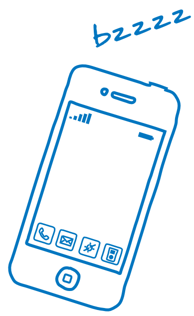

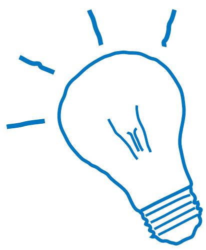

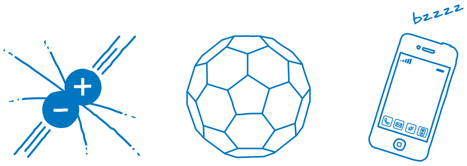

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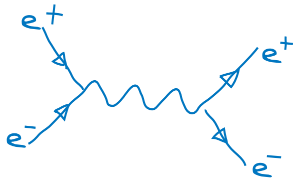

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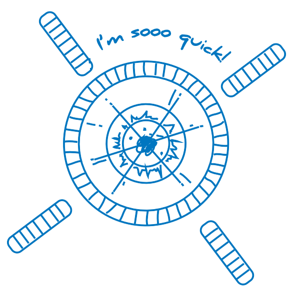

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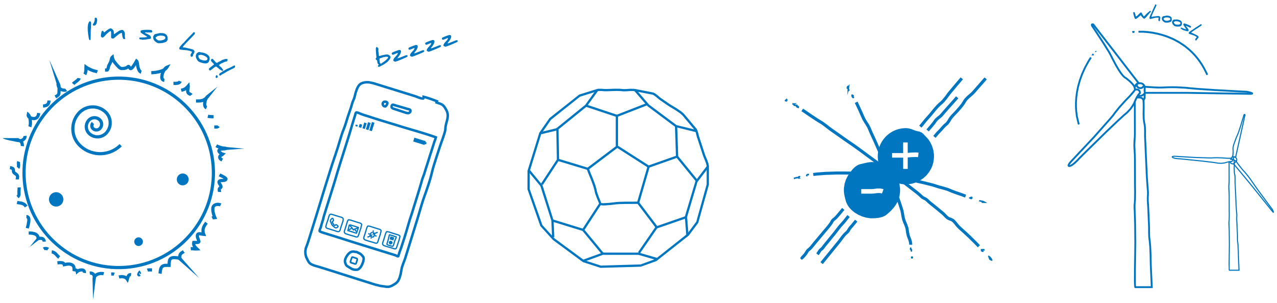


A very warm welcome to the handbook for the 'Explore Your Universe: Atoms to Astrophysics' project.

Explore Your Universe is a partnership between the UK Association for Science and Discovery Centres (ASDC) and the Science and Technology Facilities Council (STFC).

STFC's work is broad and far-reaching, touching on everything from fundamental research into the elementary building blocks of matter, to using pioneering technology to gaze out at our universe and investigate the birth of galaxies, with almost everything in between.

ASDC is the largest network of publicly accessible informal science and family engagement organisations in the UK. ASDC works to bring together this network to support development, knowledge exchange, and to support the sector's needs through coordinating national projects, such as this one, and representing the sector at Government level.

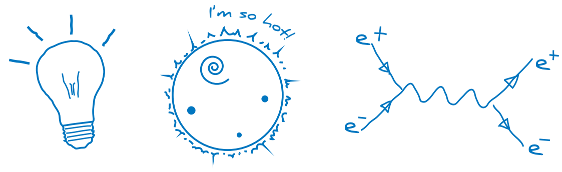
Together the membership, which is made up of thousands of dedicated science engagement professionals, reaches 20 million visitors a year, to accomplish the shared vision of supporting a society where people are intrigued, inspired and involved with the sciences. STFC have a strong strategic commitment to sharing their stories and technologies with young people and their families, audiences we know the ASDC membership has in abundance.

This project provides the opportunity to bring together some of the most fascinating and diverse science in the country with the talents and infrastructure of the nation's largest network of science engagement organisations.

The vision for the project is to inspire a new sense of excitement amongst young people and their families. To achieve this we have put together a set of core equipment that we are providing to 10 ASDC member centres who were selected via an open tender process. ASDC is also providing training and other resources to support the centres. Furthermore, STFC-funded scientists and engineers will be trained in science engagement skills, to help encourage stronger links between STFC and Science and Discovery Centres and their visitors.

The 10 Science and Discovery centres involved in the project

These centres will work with scientists and engineers to bring their science to schools and families.



The partnership began in early 2012, with a short research project, looking at what was already available across the nation in terms of hands-on physics activities; from science centre and museum workshops, to outreach activities developed by researchers including STFC's Small and Large Awards schemes. A panel of experts in physics outreach and communication was also brought together to form the 'science and engagement advisory panel'.

Already the partnership has delivered a total of 18 grants to centres to encourage and support activities celebrating space and building partnerships with astronomy experts through stargazing events.

This handbook is intended to be the launch pad from which you can begin, widen, or simply reinforce your offers around the physical sciences, for example, via public shows, curriculum-linked workshops for school groups and family activities. It is intended to be a flexible resource, so that you can use it to meet the needs of your audiences, and play to the strengths of your centre.

Whether you're starting from scratch or building on pre-existing programmes, in this handbook you will find everything you will need to use the equipment we will be providing, and deliver the workshops and shows that have been newly developed by the lead partners, Jodrell Bank Discovery Centre and the National Space Centre.

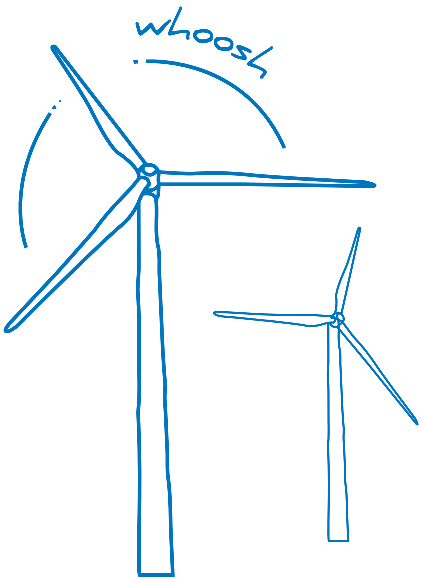
Of course this isn't the be all and end all of what the project has to offer. In addition to this handbook we have developed a brand new website where you will find a plethora of extra resources.

www.ExploreYourUniverse.org

We have designed this website to be a breeding ground for new ideas, and so on top of our regular updates, we invite you to contribute your thoughts and developments. In the future we hope this vibrant network can innovate together.

Please make special care to locate, read and understand the Health and Safety information in section 2 of the handbook, which relies on risk assessments provided by CLEAPSS (further support for our Scottish members is provided by SSERC).

The Science and Technology Facilities Council carry out some of the most exciting and ground-breaking research in the world. Its scientists and engineers are at the forefront of knowledge and have many new scientific and personal stories to tell. Together with the Association of Science and Discovery Centres, these stories can now be shared with school students and families across the UK.



With warm wishes
The Explore Your Universe Project Team

Key Project Dates

Bidders' conference call	16 August 2012
Deadline for applications	Midnight on 9 September 2012
Notification of success	20 September 2012
Science Centres Training Academy at the National Space Centre in Leicester	14-15 November 2012
Training academy for researchers and scientists at At-Bristol Science Centre	29 November 2012
Training academy for researchers and scientists at Jodrell Bank Discovery Centre	7 December 2012
Delivery of complete equipment	9 January 2013
Grant Payment 1 to centres - £2,500*	April 2013
National Meeting	Summer 2013
Deadline for delivery of all workshops by new organisations	15 November 2013
Final report from centres*	20 November 2013
Final submission of evaluation from centres*	20 November 2013
Grant Payment 2 to centres - £2,500*	December 2013
Project ends and ASDC report back to STFC on outcomes	9 January 2014

*Full details on the reporting and evaluation schedule, including requirements can be found in the Evaluation section of this handbook.

Explore Your Universe Partners and Acknowledgements

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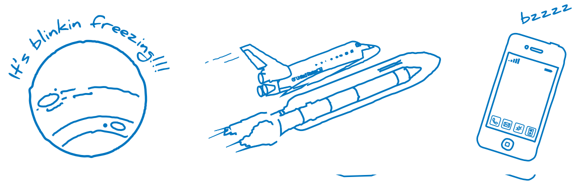
More



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Management board

Organisation	Name	Role
Independent	Dr Nick Winterbotham	Chair of the management Board
ASDC	Dr Penny Fidler	Programme Director and ASDC CEO
ASDC	Dr Michaela Livingstone	Project Manager and Secretary to Management Board
STFC	Dr Neville Hollingworth	Science in Society Department
STFC	Dr Robin Clegg	Science in Society Department
STFC	Julia Maddock	Communications Department
Based at the Royal Society	Dr Rosalind Mist	Advisory Committee on Mathematics Education (ACME) Head of Secretariat
Jodrell Bank Discovery Centre	Dr Teresa Anderson	Chair of the Science and Engagement Advisory Group and Director of Jodrell Bank Discovery centre

More →

Science and engagement advisory panel

Organisation	Name
Jodrell Bank Discovery Centre	Dr Teresa Anderson (Chair)
Association for Science and Discovery Centres	Dr Penny Fidler
Association for Science and Discovery Centres	Dr Michaela Livingstone (Secretary)
Cardiff University	Dr Chris North
Chair of British Interactive Group	Andy Lloyd
Diamond Light Source	Laura Holland
Durham University	Dr Paula Chadwick
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Rutherford Appleton Laboratory	Dr Suzie Sheehy
Science Oxford	Dr Ian Griffin
Simon Langton Grammar School	Dr Becky Parker
University College London	Dr Lewis Dartnell
University of Birmingham	Prof Peter Watkins

Many thanks to all those above who have advised the project, for example by taking part in the project 'Charette' at the start, or by advising informally throughout the project.

More

Thanks also to those who participated in the research project and have provided additional support from the following organisations:

- STFC facilities
- Institute of Physics
- South East Physics Network
- CERN
- Dark Sky Discovery
- Armagh Planetarium
- At-Bristol
- Centre for Alternative Technology
- Centre for Life
- Dundee Science Centre
- Intech
- Magna Science Adventure Centre
- Manchester Museum of Science and Industry
- National Museum Wales
- National Museums Liverpool
- National Trust's Woolsthorpe Manor
- Royal Observatory Edinburgh Visitor Centre
- Science Oxford
- Techniquest
- Techniquest Glyndŵr
- The Observatory Science Centre
- Thinktank
- University of Oxford
- Wiltshire Astronomical Society

We would also like to give special mention to Jeff Lashley, Josh Barker and Megan Whewell from the National Space Centre, and Dr Helen Featherstone from the University of Exeter for their contributions.

The Equipment List

At the core of this project sits the set of equipment that we will be providing you with. This equipment kit is intended to be flexible; it can be used by your staff and the scientists and engineers you work with to demonstrate a multitude of different concepts.

In this section you will find briefing sheets that contain information to help you get to grips with using the equipment, some suggested activities, and also descriptions of links to STFC activities and applications. You will also find the health and safety advice, troubleshooting advice, and a list of suppliers should you wish to expand your kit.

Don't forget to check the website, **www.exploreyouruniverse.org** which we will be updating with extended information, links to interesting resources and more activities ideas. We would be delighted if you would also share your comments and ideas, too.

The List!

1) Thermal imaging camera

a. Case

b. Tripod adaptor

2) Solar telescope

a. Case

b. Tripod

c. Bespoke video camera adaptor

3) iPad (64Gb, WiFi only)

a. Camera connector kit

b. VGA adaptor

Optics box

4) Spectroscopes

5) Discharge tubes

a. H

b. He

c. N_2

d. O_2

e. Hg

6) UV lamp

7) Infrared source (remote control)

8) Laser pointers

a. Red

b. Green

9) Optical fibre cable

a. S-shaped prism

10) Laser optics kit

11) White LED light source

a. White light accessories kit

12) UV pens and diodes

13) Diffraction grating slides

14) Polarising filter slides

15) Slinky spring

Materials box

16) Aerogel

17) Meteorites

a. Stony slices

b. Iron

More

The List Continued

18) Memory metal

19) Ferrofluid

a. Ferro bar magnets

b. Iron filing bubbles

20) Superconductivity Kits

21) Van de Graaff Generator

22) 'Salad bowl' particle accelerator

a. Acrylic domes

b. Aluminium tape

c. Cables

d. Crocodile clips

e. Nickel coated ping pong balls

23) Plasma ball

a. Fluorescent tubes

24) Liquid Nitrogen handling equipment

25) Cloud chamber

26) Scale model of the Solar System

Equipment Briefing Sheet / 1

Infrared Camera

Overview

The infrared (IR) camera is a device that can detect IR radiation produced by objects due to their atomic/molecular vibrations and associated temperature. This allows us to find out about the temperature of objects without having to have physical contact with them.

How it works

The human eye detects visible light waves (or visible radiation). There are other types of light (or radiation) which the eye cannot see.

The IR camera gives a visual representation of the thermal infrared energy emitted by objects. It detects infrared energy and converts it into an electronic signal, which is then processed to produce a visible light image which is usually colour-coded to show correlation with a source's temperature.

1) What other kinds of light are there?

Visible light is just a small part of a range of light radiation called the electromagnetic spectrum. The electromagnetic (EM) spectrum includes gamma rays, X-rays, ultraviolet, visible, infrared, microwaves, and radio waves. The difference between these different types of radiation is their frequency (and hence energy also).

The frequency and energy of EM radiation increases from radio waves to gamma rays (see EM spectrum slides in Masterclass presentation).

All EM waves travel at the same speed in a vacuum – the speed of light.

At GCSE level you can discuss the idea of the wave equation:
wave velocity (metres per second) = wavelength (metres) x frequency (hertz)

Since the speed of all EM waves is constant, if the frequency increases (more waves produced per second) the wavelength decreases (gets shorter).

2) What gives off infrared radiation?

Anything with a temperature above absolute zero (-273°C) will emit IR radiation. The hotter an object is the more IR radiation it will emit per unit mass. This allows a direct link to be made between the amount of IR radiation observed and the temperature of the object.

3) How can infrared radiation be used?

Apart from using the IR radiation an object emits to measure its temperature, IR radiation is used in a variety of technologies to send or to receive information. Uses include television remote controls, search and rescue cameras, and even the Kinect on the Xbox 360.

Experiments to try

1) Heat transfer

The IR camera allows heat transfer to be observed. The three methods of heat transfer are conduction, convection and radiation. Radiation needs no particles as it transfers as an EM wave alone. Conduction and convection on the other hand require particles to be present. These particles can interact and transfer heat.

This experiment works best on a non-carpeted floor. A volunteer should be selected and asked to remove their shoes and stand on the spot without moving their feet at all. When the feet are observed through the IR camera they will appear brighter, and therefore warmer, than the floor. When the volunteer steps back, a set of footprints invisible in normal light should be visible on the IR image of the floor where its temperature has risen due to the volunteer's heating effect via their feet. These footprints will fade over time as the locally heated floor cools down again.

2) Looking at hot and cold water mixing

One of the principal uses of IR is in the field of Earth Observation Science (EOS). Since it would be impractical to physically measure the temperature of the oceans with a thermometer on a regular continual basis, space based IR detectors are used to scan the oceans and calculate the temperature using the IR data obtained.

This can be demonstrated by boiling some water and pouring it into a tray of colder water. As the waters mix, temperature-driven currents are set up, which are clearly visible as different colours on the IR camera's image.

3) Observe someone wearing glasses

If someone is wearing spectacles with glass lenses they appear black on the IR camera image. This is because the IR being produced by the person's eye sockets and eyeballs is being reflected/absorbed by the glass rather than being transmitted through it. When the person removes their spectacles the IR being emitted from their eyes is no longer reflected/absorbed and so the eye sockets are clearly visible on the IR camera image.

4) The bin liner analogy

Another way that IR is useful is in astronomy, particularly when observing distant stars. If a star is in a nebula (a region of dust and gas in space) then the star will be difficult if not impossible to see in the visible part of the EM spectrum as so much visible light is absorbed by the dust/gas. This can be represented by having a volunteer stand in a bin bag. It will be impossible to see their legs in visible light, but as soon as you turn the IR camera onto them, suddenly their legs become clear as the IR they produce is absorbed to a much lower degree by the bag material than visible light is. In much the same way IR space observatories can be used to investigate regions of star formation where the infrared radiation produced by stars within penetrates the dust clouds much more efficiently than the visible light produced.

5) Standing in front of a reflective surface

Just like visible light, IR can be reflected. If a volunteer stands in front of a window or a whiteboard, when the camera is turned towards that surface, a ghost-like IR reflection can be observed.

Applications

One of the main applications of IR radiation that the STFC is involved in is IR space observatories. These giant IR detectors perform a range of tasks and are currently helping to further our knowledge of the structure of our Universe.

A key example is the Herschel Space Telescope which is studying the formation of galaxies in the early universe and investigating the creation of stars. To do this it is cooled down by liquid helium to incredibly low temperatures (only a few degrees above absolute zero) so that even the faintest IR sources can be observed. It also resides far away from the Earth at a point called the L2 Lagrange point, 1.5 million km further from the Sun than the Earth is. This large distance greatly reduces interference to the telescope's observations from IR radiation produced by the Earth.

Another space mission that will focus on the IR part of the EM spectrum is the James Webb Space Telescope. This huge telescope with an enormous 6.5m super cooled mirror will aim to observe the very oldest, earliest galaxies in the Universe. This is a particularly notable mission because one of the key experiments on board is MIRI, the Mid Infrared Instrument, which has both a camera and a spectrograph to allow it to analyse the spectra of the objects the James Webb Space Telescope observes. This is an instrument designed and built in the UK with STFC funding.

Note: For higher level 14-16 masterclasses the idea of red shift can be discussed. See masterclass presentation notes for more information.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Notes

Equipment Briefing Sheet / 2

Solar Telescope

SAFETY NOTE:

The Sun should **NEVER** be looked at directly – either by the naked eye, normal telescope, binoculars or any other device that has not been specifically designed to do so.

Overview

The Coronado solar telescope is a purpose built telescope that allows safe, direct observation of the Sun. Details on the sun such as solar flares, sunspots and granulations can be seen using it.

How it works

This solar telescope uses a "hydrogen-alpha" filter fitted to the lens of the telescope. This filter is specially designed to filter the light from the sun to make it safe to view. The filter prevents concentrated solar radiation from damaging an observer's eyes. Only devices with these filters should ever be used to look directly at the Sun.

1) Why is a special telescope needed to observe the sun?

The Sun emits electromagnetic radiation across a wide range of wavelengths. It is particularly strong in the visible and ultraviolet part of the spectrum. Even without a telescope these wavelengths of light can damage the retina in the eye if observed directly. This problem is compounded further when using a telescope to concentrate and focus these rays. As a result, in order to safely observe the Sun it is necessary to filter out the majority of the light emitted.

2) What is the Sun?

The Sun is a star – a ball of gas and plasma powered by nuclear fusion in its core. At 150 million km distance, a solar telescope is needed to see it in any detail.

3) Why will the telescope have to be repositioned often?

The Sun moves across the sky from East to West over the course of a day. In reality this is due to the rotation of the Earth about its axis rather than the Sun sweeping across the sky.

4) How could better images of the Sun be obtained?

The easiest way to see the Sun in more detail is to use a bigger telescope, however increasing the size of your telescope can only go so far. Atmospheric absorption and turbulence scatters and distorts light that arrives from the Sun, limiting how clear pictures can be. To get rid of this distortion it is necessary to place the telescopes observing it higher in, and ideally above, the atmosphere . To get the best possible solar imagery, scientists have launched several solar space telescopes such as SOHO (Solar and Heliospheric Observatory), STEREOs A and B (Solar Terrestrial Relations Observatory) and SDO (Solar Dynamics Observatory).

Experiments to try

The following are some experiments you can try related to the solar telescope:

1) Finding the Sun

Before observation can begin, it is necessary to position the telescope so that the Sun is centered within the viewer. Firstly, point the telescope in the general direction of the sun. Then the tripod needs to be adjusted using the knobs until a bright spot on the small Sun finder can be seen.

At this point the Sun should be visible in the solar telescope. By making very small adjustments using the knobs, the Sun can be fully centered.

The telescope does not have a focus function as such. Instead the image will need to be 'tuned' depending on the features being observed. By making small adjustments with the knob on the telescope and the band surrounding the telescope tube, it is possible to tune the telescope to see the prominences and solar flares at the edge of the Sun, or the sunspots and granulation on the disc of the sun.

It will be necessary to adjust the tripod to keep the Sun in view as the Earth rotates and the Sun changes its apparent position in the sky.

2) Looking at solar prominences and flares

Around the edge of the Sun, arcs of material can often be seen. These are known as solar prominences and are closely associated with solar flares and coronal mass ejections. Both of these are examples of material being ejected from the sun.

Record how many prominences can be seen over the observing session. This can tie in with the SOHO and SDO apps on the iPad to monitor solar activity.

3) Observing sunspots

Sunspots are temporary, dark (in comparison to the surrounding parts of the Sun's disc) spots that occur in the photosphere (the light emitting region) of the Sun. They are caused by magnetic activity and are closely linked to solar activity which seems to undergo an 11 year cycle.

Applications

As mentioned above, there are several solar space observatories that have been launched to study the Sun in detail. STFC scientists and engineers have been involved in the design, construction and analysis of data for several of these.

Notable examples include SOHO (the Solar and Heliospheric Observatory) which observes the Sun primarily in the UV part of the EM spectrum, and STEREO – a mission involving two solar observatories in tandem monitoring not only the Sun, but also the space between the Sun and the Earth. These two spacecraft have allowed scientists to construct stunning 3D images of the Sun, and much of the analysis for this is conducted by scientists at STFC's RALSpace in Oxfordshire.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 3

iPad

Overview

The iPad is a tablet device that can be used as a platform to use applications (apps), a tool to research using the internet, present information, and much more.

The iPad we have provided you with is an iPad 3, 64Gb with wireless internet (WiFi) capabilities, but cannot connect to mobile data networks (such as those used by mobile phones to surf the internet)

We have also provided:

- A VGA adaptor so that you can display the iPad screen on to a projector
- A camera connection kit, which allows you to transfer images between devices, such as using an SD card or a USB cable

The device is very simple to use. You will find a small, quick guide included in the box, and we've downloaded the full user guide on to the iPad (located in the iBooks app).

Apps

We have pre-loaded the iPad with a number of applications, or apps, which we think are fantastic, either as sources of information, fun relevant games, great ways of displaying media, or simply as a tool to help you plan and deliver events at your centre. You can also set up your social media accounts on the iPad to allow for easier posting and sharing on-the-go.

The apps pre-loaded are listed here and we have written some basic descriptions of these apps which can be found on the website. We encourage you and your colleagues to take the time to explore them for yourselves. You'll find there's a lot of overlap in some of the content, so it's really up to your centre to find what works best for you.

Many of these apps require a WiFi connection, and if you do not have this facility in your centre, you might struggle with some of them (we have indicated this on the additional iPad information on the website).

You might notice that some apps display quite small on the screen. This will be because they were initially designed for the iPhone. You'll see a '2x' button in the bottom right hand corner of these apps – this will make the apps larger, but may make some of the graphics pixelated, or gainy. Keep an eye on the apps store for updates which may address this.

Applications provided:

Wow!

Physics

3D Sun
Angry Birds Space
Arianespace
AstroApp
Best ISS 3D
Cassini HD
Comet Quest
ESA App
ESA Bulletin
ESA cryostat HD
ESA DUE
ESA OSHI
ESA WIS
ESO Top 100
Exoplanet
FLIR Tools
Galaxy Zoo
Google Earth
GoSatWatch
GoSkyWatch
Hubble Top 100
Mars HD
Molecules
Moon HD
NASA App HD
NASA Science
NASA TV
NASA Viz
NBI Colliderscope
Next Step Mars
Particle Zoo
Planet Finder
Portal To The (PTT) Universe
PS @ ATLAS
pUniverseHD
SatelliteInsight
SDO (Solar Dynamics Observatory)
Space Images
Spacecraft 3D
SpacePlace
TED talks
The Scale of the Universe
Worlds Apart

Tools

Dropbox
Skype
Calculator
Videolicious
QR Reader
Simple Paint

Security

We have set the iPad up with an Apple ID and password, which you will be provided with at the training academy. You can change the email address and password and will not lose the purchases that we have made. You can do this by using the 'iTunes and App Stores' menu in 'Settings'.

You will need to change the payment information before you do anything else. We will have taken you through this at the training academy. Please be aware that we have set these iPads up and made purchases using a dedicated credit card, and we will be aware if any unauthorised purchases are made on it.

Your Apple ID password is required every time you make a purchase. This means that without it, no one can make unauthorised purchases.

For added security, we have also set up a device pass code which needs to be input whenever the device is used. This will mean your content is protected from unauthorised use. This code is provided in the box of the iPad, along with your Apple ID information. You can change this in 'Settings>General>Passcode Lock'. You will also find a menu to set restrictions on the use of various applications in this menu.

If you experience any problems you can make use of Apple's dedicated iPad support website **http://www.apple.com/support/ipad/**.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 4

Spectroscope

Overview

Spectroscopes are used to split visible light into a spectrum of light that resembles a rainbow. They use a diffraction grating to do this (see sheet on diffraction gratings for more information on these). This allows us to see all the individual wavelengths (colours) of visible light which make up the light coming from a particular source. By looking at different light sources we can see that they often emit different wavelengths. The differences act as a fingerprint to help us identify what the source is.

How it works

1) Why can I see a rainbow if the light source looks white?

Because white light is made up all the colours of the rainbow and the spectroscope can split these colours up.

2) Why is there a slit at the end of my spectroscope?

To make sure only a very small amount of light from the source gets into the spectrometer and that it is the only source of light entering the spectrometer.

3) How does the spectroscope split white light into different colours?

Different wavelengths of light (i.e. different colours) are bent different amounts by something called a diffraction grating (see diffraction grating sheet for more information here).

4) Why do I sometimes see very bright lines?

Some sources will give off lots of light at a particular wavelength (colour) which makes the brighter lines. We call these emission lines because the source is emitting at that wavelength.

5) Why do I sometimes see black lines?

Some materials will absorb certain wavelengths (colours). This means the light does not reach our eyes and so we see black lines where parts of the spectrum are missing.

6) Why don't all lights give the same spectra?

The different lights all contain gases that are made of different elements. The spectra you see are due to the composition of the specific wavelengths of light that come from particular elements.

Experiments to try

1) Look at an old fashioned light bulb through the spectrometer. What can you see? You should be able to see a rainbow but with some black lines on it.

2) Look at different energy saving light bulbs. You will also see rainbows with black lines but the black lines may be in different places.

3) Look out of the window (NOT at the sun). Again you should be able to see rainbows, possibly with black lines.

4) Look at the discharge tubes when switched on with different gases in them. You should only be able to see a few coloured lines and not a whole rainbow. These coloured lines are emission lines unique to the gass in the tube.

5) If you have the means to do a flame test by burning different metal salts dissolved in alcohol then you can look through the spectrometers at these spectra. Again the number of lines should be limited and you should not see a full rainbow.

Applications

Spectroscopes are used on many different telescopes which are operated by STFC. They can be used to study the evolution of many different objects in the universe.

As stars evolve, there is a change in the chemical elements that make them up. At the start of a star's life it will contain a lot of hydrogen. The hydrogen atoms in the star are squeezed together under very high pressures until they join together to become helium atoms. This process is called nuclear fusion and is what powers a star. Helium atoms can also be squeezed together to form heavier elements and it is possible for elements as heavy as iron to be formed via this process.

As the star evolves the amount of hydrogen in it gradually decreases and the amount of heavier elements gradually increases. By using a spectrometer we can see how much of each element there is by looking at the spectral lines. We can use this information to work out where in its life cycle the star is.

The Herschel telescope studies the evolution of galaxies, stars and planetary systems. The European Southern Observatory and the KECK telescopes also have spectrometers for looking at the evolution of things in the universe.

Spectrometers can also be used for looking at Exoplanets (planets outside our own solar system). The chemical composition of a planet's atmosphere can give an indication of whether the planet is likely to be able to support life.

Extra resources

For extra resources, videos, updates, and more, please visit the website
www.exploreyouruniverse.org

Equipment Briefing Sheet / 5

Discharge Tubes

Overview

A discharge tube is like a strip light, but the ones in the set contain a range of different gases. The different gases make them appear different colours when lit. If you look at the different tubes through a spectroscope you can see bright lines or dark lines which give us more information about the gas.

How it works

1) How does the light work?

A voltage from the mains electricity supply is applied over the length of the tube. This voltage causes a current to flow through the gas, which makes the gas glow.

2) Why do different gases give different colours?

Simple explanation

Electrons are given energy from the voltage which is applied. This energy is then given off as light. Electrons in different gases need different amounts of energy and these different amounts of energy correspond to different colours.

14-16 year old explanation

The electrons in atoms occupy discrete energy levels. Electrons need to be given the right amount of energy to move to a higher energy level. When they move back down to lower energy levels the energy is given off as a photon with a particular energy. Different energy photons correspond to different colours of light.

Experiments to try

1) Put tubes with different gases in into the discharge tube holder and observe the different colours different gases make.

2) Look at the emissions using the spectroscope and see if you can spot the different emission lines which are created.

3) If two discharge tubes look the same colour to the naked eye try comparing them with spectroscopes. They should look different through the spectroscope (i.e. the emission lines should be in different places).

Applications

The applications are on the spectroscope sheet since these discharge tubes are being used to illustrate spectroscopy.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 6

Ultraviolet Lamp

Overview

The Ultra Violet (UV) lamp is a lamp that as well as emitting violet light that we can see also emits a lot of UV light, which we can't see. UV light is a type of light with a wavelength shorter than visible light. It has a higher energy than visible light so therefore it is more dangerous. UV light has enough energy to break down cell walls and so can be harmful to human health in large enough quantities. Visible light does not have enough energy to be able to break down cell walls and so it is not harmful to us.

How it works

1) What does UV light do to you and why?

Small amounts of UV light help us to make vitamin D that we need to stay healthy. However, high exposure to UV light can burn the skin (sunburn, which is actually a type of radiation burn). It can also cause premature aging of the skin as UV light damages collagen fibres leading to a decrease in skin elasticity. Exposure to a high enough dose can even lead to skin cancer through damaging DNA.

2) How do we use UV light?

UV light is used to sterilise equipment and surfaces as it kills germs. It is used for security checks. It is also used in some detergents which feature optical brighteners which emit visible light when exposed to UV making the colours of clothes seem brighter.

Experiments to try

1) Put some sun cream on your hands and then put your handprints in a piece of paper. The paper and sun cream should be the same colour. You can't see the handprints in normal light but when you hold the piece of paper up to the UV light you will be able to see them. This shows that sun cream blocks UV light.

2) Looking at driving licenses and banknotes under the UV light. You may be able to see additional security features which are not visible in normal light.

3) Looking at people's clothes under the UV light. They may glow since a lot of washing powder contains optical brighteners

4) Look at the end of people's nails under the UV light. They will glow due to their high calcium content.

5) It is possible to buy pens whose ink is only visible in UV light. You can write secret messages and create puzzles using this technique (see UV Pens and Diodes briefing sheet).

6) It is possible to buy beads which glow in UV light.

Applications

Ultraviolet light can be used in many different ways by scientists. It can be used by astronomers to look at objects in the universe that emit a lot of light at this wavelength to find out more about these objects. Examples of objects that emit a lot of this light are young stars and stars nearing the end of their life. We cannot have ultraviolet telescopes here on earth though, since our atmosphere absorbs this type of light. Therefore we can only use space telescopes to view objects at this wavelength.

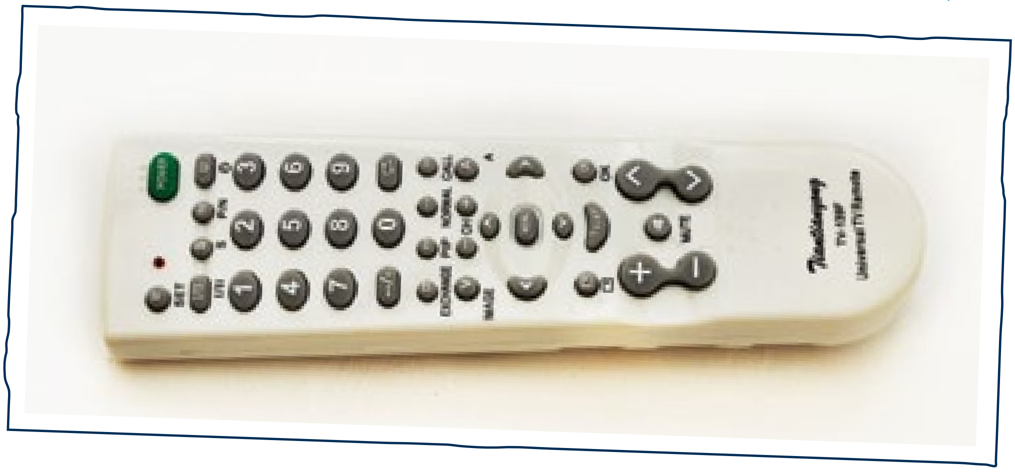
Ultraviolet light is also produced by synchrotron light sources, such as the Diamond Light Source in Oxfordshire. The Ultraviolet beamline at the Diamond Light Source is used to look at the structure of proteins and the way drugs might interact with them in order to develop new drugs.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 7

Infrared Source



Overview

The infrared (IR) source (in this case a TV remote control) is a source of infrared radiation. This radiation has a wavelength slightly longer than red light, hence its name. We cannot see this part of the spectrum but we detect this radiation as heat. The infrared camera can be used to detect this type of radiation. Everything around us is emitting infrared radiation. Infrared radiation is not known to be harmful to health.

How it works

1) How is the IR produced in a TV remote control?

The IR is often produced with an LED (Light Emitting Diode). Pushing a button on the remote control completes a circuit and switches the LED on. In this case, the 'light' which is emitted is in the infrared part of the spectrum.

2) How directional is the IR beam?

The IR beam is very directional. You may have noticed this since your TV doesn't usually pick up a signal from a remote control unless you point the remote control at the TV – or perhaps reflect the beam directly off a wall and then towards the TV.

3) How does a TV pick up the IR signal?

The TV picks up the IR pulse like a piece of binary code. A microprocessor in your TV then interprets and executes the command.

4) What else is IR used for?

The most familiar use of IR is in night vision cameras. These cameras can 'see' in the dark because they are picking up heat (IR) and not light. Other scientific applications of IR are discussed in the applications section.

Experiments to try

1) Point the remote control at the thermal imaging camera. Can you see the IR beam?

2) Can you see the IR beam reflecting off any surfaces by using the IR camera? You will find that some surfaces reflect the beam and others will transmit the beam.

Applications

IR astronomy – see IR camera briefing sheet

The ALICE accelerator at STFC's Daresbury Laboratory generates a high-energy electron beam which is used to drive a unique light source, known as a Free-Electron Laser, or FEL. A FEL is a very special type of light source: it generates very short, high-power pulses of coherent light (like a conventional laser), but is tuneable over a wide range so that the colour of the light can be changed. The ALICE FEL operates at infrared wavelengths in the 4 to 20 μm range, though conventional lasers do not have this range of tuneability.

The ALICE FEL is being used by a team of physicists and clinicians to test for cancer in oesophageal tissue samples. This cancer is the 9th most common form of cancer in the world - it is highly aggressive and is often terminal. Using intense pulses of infrared light from the FEL coupled with an imaging process known as 'SNOM' (scanning near-field optical microscopy), the research team are able to detect very small cancerous tumours, allowing early treatment with an improved prognosis for the patient. The technique also improves the clinicians' understanding of the development mechanism for this cancer, and sheds light on how drugs interact with both cancerous and healthy cells.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 8

Laser Pointers

Overview

Laser pointers are an everyday example of a laser. Two different coloured laser pointers have been provided: red and green. Lasers are light sources which are described as both spatially and temporally coherent. This means that they produce pencil like beams which don't spread out (spatial coherence) and all the waves are the same frequency (colour) and in phase with each other (temporal coherence).

How it works

1) What does laser stand for?

Laser is an acronym. It stands for Light Amplification by the Stimulated Emission of Radiation.

2) How does a laser work?

First a material has to be produced where electrons are in excited states around atoms. This can be done by applying a voltage across certain types of material. When electrons drop back down to their ground state from their excited state they emit a photon of light of a particular colour. This light can then stimulate the emission of more photons. The power supply will continue to pump the electrons back up to their excited state so that more stimulated emission can take place.

3) Are lasers dangerous?

They can be. Some are more dangerous than others. Lasers are defined by belonging to a Class (1, 2, 3A, 3B or 4). Class 1 and Class 2 lasers are unlikely to do you any harm unless you stare into the laser beam. If you do this you risk damaging your eyesight within a fraction of a second. Class 3A lasers do pose a small risk of damaging your eyesight before your blink reflex kicks in. Class 3B lasers will damage your eyesight immediately and Class 4 lasers are not only dangerous to your eyesight but can burn your skin as well.

4) Why do laser pens only come in limited colours?

Laser light from a particular material is just one colour. This is because electrons can occupy only discrete energy levels; they can't be at whatever energy they want. When the electron goes from the excited state to the ground state an amount of energy which is the same every time is released. The amount of energy corresponds to a particular colour. The gas in the red laser pen is often Helium and Neon. The process in a green laser pen is more complicated and involves several different materials to achieve lasing.

Experiments to try

1) Shine the laser onto a wall at a large distance from you (make sure there are no people between you and the wall). The spot should look just as focussed there as when you are stood right next to the wall.

2) Try looking at the laser spot on a wall or surface through a spectroscope. You should only see a single colour, not a spectrum.

3) Shine a laser through a prism. You won't get a rainbow like you do with white light because laser light is monochromatic.

4) Lasers can be used to show how Perspex blocks (showing refraction) and mirrors (showing reflection) work.

Applications

Taken from CLF Highlights

For 60 years scientists have been exploring how to generate energy by harnessing the nuclear fusion reactions which power the Sun. The fusion of the two heavier isotopes of hydrogen, deuterium and tritium, at temperatures of 100 million degrees, to produce helium and energy-carrying neutrons would provide a safe, controllable, carbon-free power source with security of supply to all nations, readily manageable waste and at scale to power our civilisation for millennia.

The advent of high-power laser systems has allowed researchers to study a fusion scheme in which a spherical pinhead-sized pellet containing the hydrogen fuel is compressed by several laser pulses. The resulting implosion heats up the deuterium-tritium mixture, creating a plasma that is hot and dense enough to cause 'ignition' marking the start of self-sustaining nuclear fusion reactions. This Inertial Fusion Energy (IFE) scheme is to be demonstrated on the US National Ignition Facility. This scheme requires the delivery of a huge amount of laser energy into the pellet in a very balanced symmetrical way, and so is not easy to achieve. Now, another route is being studied, called fast ignition, which should require much smaller lasers and offer a cheaper, more practical route to a commercial fusion reactor.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 9

Optical Fibre and S-shaped Prism

Overview

An optical fibre is used to carry a signal in the form of light from one location to another. The signal will contain information of some description (e.g. messages being sent over the internet). Light normally travels in straight lines but optical fibres can be used to take light along curved paths and around corners as well. The S-shaped prism is essentially a large optical fibre that allows you to see what is happening more easily. The S-shaped prism's shape cannot be changed but the optical fibre can change shape.

How it works

1) Why does the light not 'escape' from the optical fibre?

The light can be shone down the optical fibre at most angles and it will not 'escape'. This is because when the light gets to the boundary between the glass fibre and the air it is reflected instead of transmitted.

2) Why does light bend at the boundary between two media?

The bending of light at the boundary between two media is called refraction. Refraction occurs because the light either slows down or speeds up when it changes medium (the speed of light is only constant in a vacuum).

3) Does light always get reflected at the boundary between two media (e.g. glass and air)?

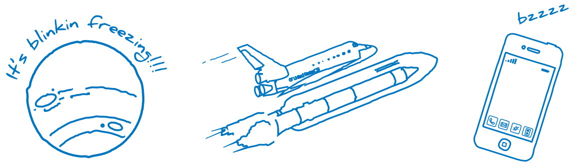
No, it doesn't. It depends on the angle that the light arrives at compared to the boundary between the two media. At angles that are close enough to a right angle (normal) to the boundary line the light will be transmitted. Even so, the light will still be bent at the boundary to some extent. Whether it is bent closer or further away from the normal (the line at right angles to the surface of the boundary) depends on the refractive index of the two materials. Glass and air have different refractive indices.

4) So what decides whether light is reflected or transmitted at a boundary?

This depends on two things: The angle at which the light comes in and the refractive indices. For any two media (e.g. glass and air), there is a critical angle beyond which light will be reflected and not transmitted. In an optical fibre, this angle is sufficiently small that reflection occurs at most angles.

Experiments to try

1) Shine a laser pen down the optical fibre. Can you see the laser light at the other end? Do not look directly into the fibre. You should be able to see the colour of the light from any angle.



2) Try bending the optical fibre and see if there is a limit to how far you can bend it before the light stops being transmitted (be careful not to snap the optical fibre).

3) Try different coloured lasers and different types of light to see if these can be transmitted.

4) Shine a laser pen down the S-shaped prism. You should be able to find some angles where the light gets to the other end and others where it does not, demonstrating total internal reflection.

Applications

Optical fibres are an everyday part of our lives. We rely on them to transport a lot of our telecommunication (telephone and internet) signals. The rate at which optical fibres can carry data is much faster than conventional telephone wires. This is why you probably all want fibre optic broadband if you can get it!

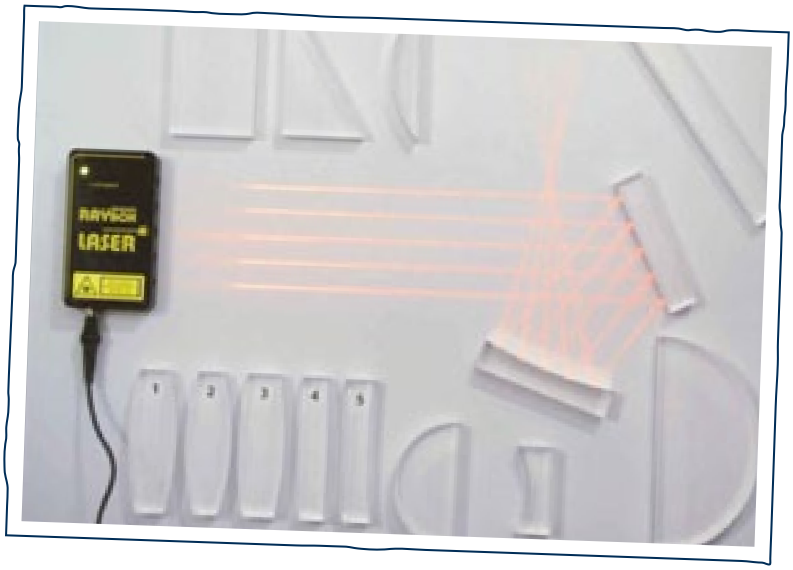
Fibre optic communications were originally developed for scientists. Experiments that collect large amounts of data such as arrays of telescopes (e.g. e-MERLIN at Jodrell Bank and around the UK) and particle physics experiments (such as the detectors for the LHC) need fast connections in order to send the data around the world to the scientists who need it.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 10

Laser Optics Kit



Overview

The laser optics kit consists of a laser ray box and a set of optical components including mirrors, lenses and other Perspex blocks. The whole kit is magnetic so it can be put on a whiteboard or other magnetic surface to enable display to large groups. The kit will allow you to explain the optics principles of reflection and refraction. It also has worksheets which allow you to show how your eye, a camera and a telescope work.

How it works

1) Why does the laser ray box have 5 light beams?

This is to show how light passing through an optical component (e.g. a lens) is affected depending on which part of the component it passes through. The central line will normally pass through the middle of the component and be unaffected, but the other beams are affected, and this can be used to demonstrate focussing, for example. It is possible to block some of the laser rays with the supplied blocking plate if necessary.

2) What is a lens?

A lens is a component which either focuses or defocuses the light passing through it.

3) Why do I have more than one type of lens?

The lenses supplied all focus the light in different places.

4) Why do I have more than one type of mirror?

The mirrors are either flat and just reflect light or they are curved and can be used to focus light.

5) What are the rectangular Perspex blocks for?

The rectangular Perspex blocks will all show refraction in some way. Refraction is when light changes direction when it passes from Perspex to air or vice versa. Please note you will not see any visible refraction if the light beam enters the Perspex block directly at right angles to one of its faces.

Experiments to try

1) Try placing each of the optical components (lenses, mirrors, and Perspex blocks) in the path of the laser beam and see what effect each has.

2) Try to come up with two ways of focussing light (you can use a lens or a curved mirror).

3) Try to come up with two ways of bending the lights path (you can use a mirror or a Perspex block).

4) Set up each of the worksheets with the correct optical components to see how cameras, your eye and telescopes work. Follow the enclosed instructions.

Applications

The correct placing of optical components is very important to astronomers. They have modified the design of telescopes over time to improve the images they get.

The first telescopes were refracting telescopes. These basically just used a lens to magnify the object which was being viewed. The trouble with lenses is that because they work by refraction they bend light with different wavelengths (colours) by different amounts and so the focus for each colour is in a slightly different place. This is called chromatic aberration.

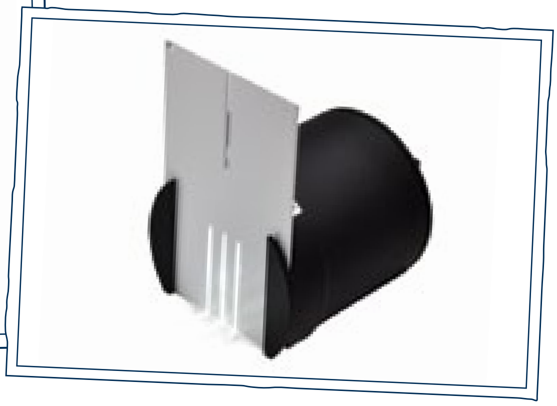
To get round this problem the reflecting telescope was invented. This just uses a curved mirror to focus the light and this focus works independently of the wavelength of the light. Both refracting and reflecting telescopes are in use to this day but reflecting telescopes do have this advantage over refracting telescopes.

Telescopes can have mirrors which are tens of metres in diameter. The European Extremely Large Telescope (E-ELT) will have a mirror diameter of 40m and is expected to come into use around 2020. Telescopes of this size can be used to hunt for planets outside of our solar system, known as exoplanets.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 11



White LED Light Source

Overview

The white light source is an LED light source that emits white light. White light is in fact a range of different colours mixed together that we see as being white. The source can be use to show how lasers, white lights and coloured lights differ.

How it works

1) Is white light really white?

No, it isn't. White light is in fact light that is made of all the colours of the rainbow (red, orange, yellow, green, blue, indigo and violet). When these colours are mixed together we see the result as white. When the light hits the side of a prism at an angle to the normal (the line perpendicular to the surface of the prism) refraction (bending of light) will occur. Different wavelengths of light will be refracted by different angles, so when they emerge from the prism (being once again refracted) the white light has been split in to its component wavelengths.

2) How can I see the different colours in white light?

If you shine white light through a prism you can see the colours of the rainbow. A prism is available in the white light source accessories kit. There are also prisms in the laser optics kit and a larger Perspex prism provided separately for using in larger groups.

3) How is white light different from laser light?

White light is a mixture of colours, whereas lasers are just one colour. Laser beams are also highly collimated (they don't spread out) whereas the white light does spread out.

Experiments to try

1) Shine the white light source (or alternatively a normal torch) on a wall. If you stand near the wall you will see the spot size is small. As you walk away from the wall you will see the spot size gets bigger. We call light sources that get bigger as you get further away divergent light sources.

2) Shine the white light source through a prism to create a rainbow. To do this you will need to use the slit plate provided (just use the single slit) and one of the lenses. Put the slit plate immediately in front of the light. Place the lens approx 20-30cm away from the light (adjust the distance until you find a place where you can see the light focus to a fairly small spot). Place the prism near to the focus point and you should see a rainbow.

3) You can shine the white light source through the diffraction grating to create multiple rainbows.

Applications

Please see the case studies in the laser optics kit briefing sheet - this equipment is just used to demonstrate how white light differs from other light.

Extra resources

For extra resources, videos, updates, and more, please visit the website
www.exploreyouruniverse.org

Equipment Briefing Sheet / 12

UV Pens and Diodes

Overview

Ultraviolet (UV) reactive inks can be used as security markers for property. When illuminated by a high energy UV light, these inks fluoresce allowing us to investigate some of the properties of UV light.

How it works

UV reactive inks contain minerals that will fluoresce when exposed to UV light. This allows them to appear invisible under visible light conditions, but visible when a UV source is shone on them .

1) What is fluorescence?

Fluorescence is the emission of light, usually visible, by a substance that has absorbed light in the form of electromagnetic radiation.

2) Why does the UV reactive ink fluoresce under UV light?

Certain minerals such as phosphors will glow under UV light because electrons in the atoms will absorb the high energy UV photons and gain enough energy to jump to a higher energy level. In order for the electron to lose this energy and return to the ground state it emits small packets of light energy called photons. The minerals in the ink have energy levels whose difference corresponds to the wavelength of visible light. As a result, as an electron relaxes to a lower energy level, visible light is emitted.

Experiments to try

UV detectives

Laminated black card is the perfect surface to mark with UV marker pens. On this laminated card write down facts about UV light and/or the EM spectrum. Then cut up the statements to create a puzzle.

In a darkened room, students can use the UV diodes to scan over the puzzle pieces and complete the statement, writing it down and relaying it to the class.

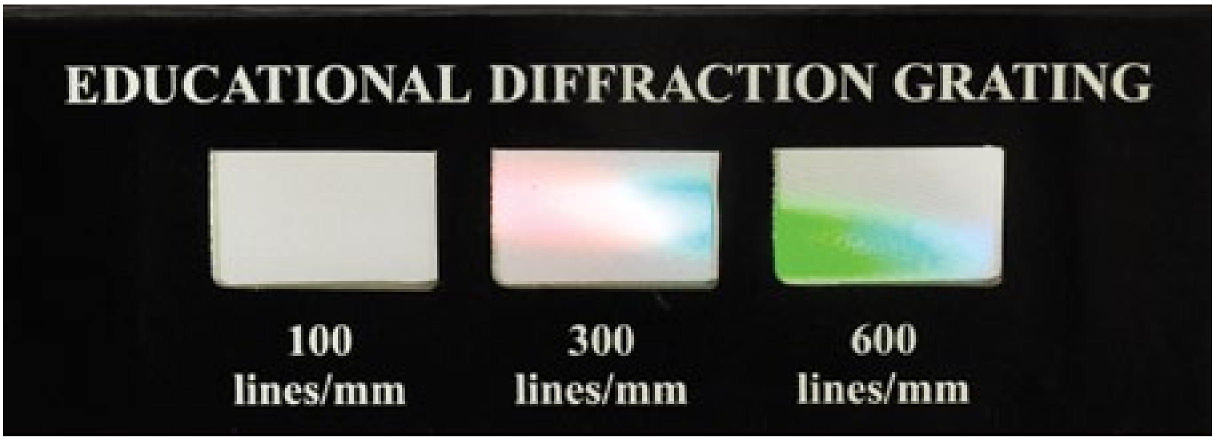
Once this is done there may be some time to hand out some blank pieces for students to draw their own UV art on.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 13

Diffraction Grating



Overview

A diffraction grating is used in optics and has a regular structure, a bit like a comb, which appears to split light of a particular colour into several beams travelling in different directions. The directions of these beams depend on the spacing of the grating and the wavelength of the light. The spectroscopes also have diffraction gratings in them. The diffraction grating splits up white light into a rainbow like a prism does but the spectrum is not continuous like a rainbow. Instead, there are separate lines for different colours.

How it works

1) What is diffraction?

Diffraction is the bending (change of direction) of waves when they encounter an obstacle. It can be thought of like water being squeezed through a small gap and then spreading out once it is through the gap.

2) What factors affect the amount of diffraction?

Diffraction is most pronounced when the wavelength of the wave and the size of the object causing the diffraction are roughly the same. The amount of diffraction seen will also depend on the wavelength (colour) of the light used and the spacing of the diffraction grating.

3) How will the number of lines on my diffraction grating affect the diffraction of light waves?

The distance between the lines on the grating will affect how much diffraction is seen. The closer the gaps are together (the more lines per millimetre) the more space there will be between the fringes (areas of light). Different coloured light will also be seen to diffract a different amount due to different colours being different wavelengths.

Experiments to try

1) Shine a laser pen through one of the diffraction gratings so that the pattern can be seen on a wall. Compare the pattern with that formed when shining a pen through another grating.

2) Try shining different coloured laser pens through the grating and see how this affects the spacing of the pattern.

3) Try shining a laser pen through the grating at different angles to observe what effect this has.

4) Shine a well focussed white light through the grating. You will see multiple rainbows formed since the different colours are diffracted by different amounts. You should see multiple rainbows with dark gaps between them in all cases. The gap size will vary with the line spacing on the grating.

Applications

Diffraction gratings are not used often in science, but the principle of how they work underlies much of modern physics. If light is shone through a crystal, the crystal acts like a diffraction grating (because it has a regular structure) and from the diffraction pattern we see we can work out what the structure of the crystal is.

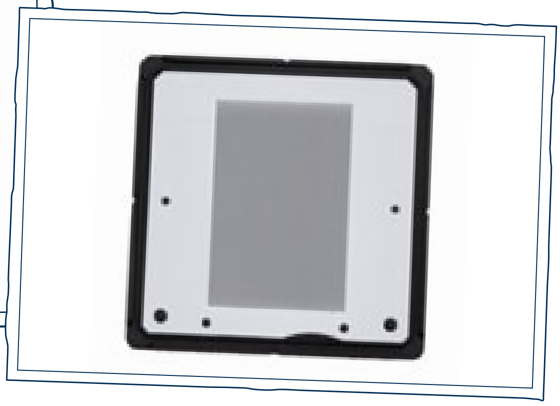
This crystallography technique is used widely on the beamlines of synchrotron light sources such as STFC'S Diamond Facility. The predecessor to Diamond was the SRS (Synchrotron Radiation Source) which was based at STFC's Daresbury Laboratory in Cheshire. Cadbury's used one of the beamlines on the SRS to look at crystal structures in chocolate. The rate at which chocolate is cooled will affect which crystal structures are formed. The ratio of different crystal structures affects the flavour of the chocolate. Cadbury's varied the rate of cooling (and therefore the ratio of different crystal structures) to improve the taste of their chocolate.

Extra resources

For extra resources, videos, updates, and more, please visit the website
www.exploreyouruniverse.org

Equipment Briefing Sheet / 14

Polarising Filters



Overview

Polarising filters only allow light with a particular polarisation to pass through them. This can both reduce the intensity of light which passes through and also only allow a certain polarisation if that is what is required. There are several different ways in which light can be polarised and different filters are required for each type of polarisation.

How it works

1) How do light waves oscillate?

Light waves oscillate transversely (see briefing sheet on slinky spring for more on this), but they don't just oscillate in one transverse direction. The electric field component oscillates in one plane and the magnetic field component oscillates at right angles to this, but also in a transverse plane. It is the direction of oscillation of the electric field which defines the polarisation.

2) Are all waves polarised the same way?

No, they are not. The electric field can oscillate horizontally, vertically or anywhere in between but remain in a constant direction as the wave travels along. This is known as linear polarisation. If the direction of oscillation is changing as the wave travels then it may be going in a circle or an ellipse. These are known as circular and elliptical polarisations. The rotation may be going to the right (clockwise) or to the left (anticlockwise) as the wave travels. These are known as right handed and left handed polarisations.

3) What does a polarising filter do?

A polarising filter only allows light with one particular polarisation through. Other polarisations are absorbed.

4) Does that mean I have to line up my filter with the polarisation of the light to let any light through?

No. If the filter lets through light polarised in the same direction as your light source then all the light will pass through. If you rotate the filter the amount of light passing through will gradually decrease until the filter is at right angles to the polarisation of your source. When the filter is at right angles to its starting position there will be minimal light transmission.

5) Are all light sources polarised?

No they are not. This means if you use an unpolarised source light will pass through the filter whichever angle you hold it at.

6) So can I use the filters to block unpolarised light?

Yes, you can, but you need two filters. If you set one filter in place and rotate the other filter slowly you should find a point when no light is transmitted. This will be when the two filters have their polarisations at right angles to each other.

7) How are polarising filters used?

One of the most common uses is in sunglasses. Reflected light is usually polarised so sunglasses reduce how many reflections you see and also reduce the overall intensity of the light reaching your eye.

Experiments to try

1) Use two filters to try to block out light sources by rotating them relative to each other.

2) Use a single filter to look at light sources and rotate the filter to find out of the source is polarised.

3) Shine a laser pen through the filters. Find out if it is polarised.
Do not shine the laser pen into anyone's eyes. Look at the laser spot on a wall or other surface.

4) Look at the discharge tubes through the filters. Are these polarised?

Applications

Sunglasses are perhaps the most common uses for polarising filters, but we can also use these filters on telescopes to block out unwanted light and get a better view of what we are trying to look at. The Keck Observatory in Hawaii has used this technique to look at black holes.

Studying black holes at the centre of galaxies is difficult. A huge amount of material is falling onto the centre in an active black hole system, and this falling material is thought to power the black hole, but scientists still don't understand this powering mechanism. One critical reason is that these black holes are just too far away for astronomers to isolate the light from them - or more accurately, the light from the compact region where the black holes are actually producing their energy.

Astronomers have looked at a small part of the light emitted from black holes - light that has been scattered as it passes through clouds of gas nearby. This scattered light can cleverly be picked up by looking through a polaroid filter just like the lens of polaroid sunglasses, which essentially blocks the unwanted light from elsewhere in the galaxy. The scattered light is polarised so the light waves all line up in the same direction and can pass through the Polaroid filter, but light from the surrounding area which is not polarised is excluded by the filter.

Extra resources

For extra resources, videos, updates, and more, please visit the website
www.exploreyouruniverse.org

Equipment Briefing Sheet / 15

Slinky Spring

Overview

A slinky spring is a coil of wire. It has a short length when compressed or can be stretched out so that it is very long. Amongst other things, it can be used to show how waves propagate through a medium. Not all waves propagate in the same way but the slinky can be used to show both types of propagation.

How it works

1) How does a wave propagate through a medium?

Waves propagate (travel) by 'oscillating' and in doing this, they transfer energy from one place to another. Waves can oscillate at right angles to their direction of travel (e.g. water waves) or can oscillate along their direction of travel (e.g. sound waves). The medium through which the wave travels (e.g. the water or the air) does not move overall but the wave still travels through it from one place to another.

2) How do light waves travel?

Light waves oscillate perpendicular (at right angles) to the direction of motion. So if you were a light wave travelling forwards you would be oscillating both side to side and up and down, but not backwards and forwards. This is known as transverse oscillation.

3) How do sound waves travel?

Sound waves oscillate parallel to the direction of motion. So if you were travelling forwards you would be oscillating backwards and forwards but not in either of the perpendicular directions. This is known as longitudinal oscillation.

4) What about other types of electromagnetic radiation?

Other types of electromagnetic radiation (Gamma rays, X-rays, Ultra-Violet, Infrared, Microwaves and Radio Waves) all travel in the same way as light.

Experiments to try

1) Get two people to hold the slinky, one at each end, with it laid out on a table. If one person shakes the slinky from side to side, this will show how a transverse wave travels.

2) Get two people to hold the slinky, one at each end, with it laid out on a table. If one person takes several of the coils and squeezes them together, and then throws them along the slinky this shows how a longitudinal wave travels.

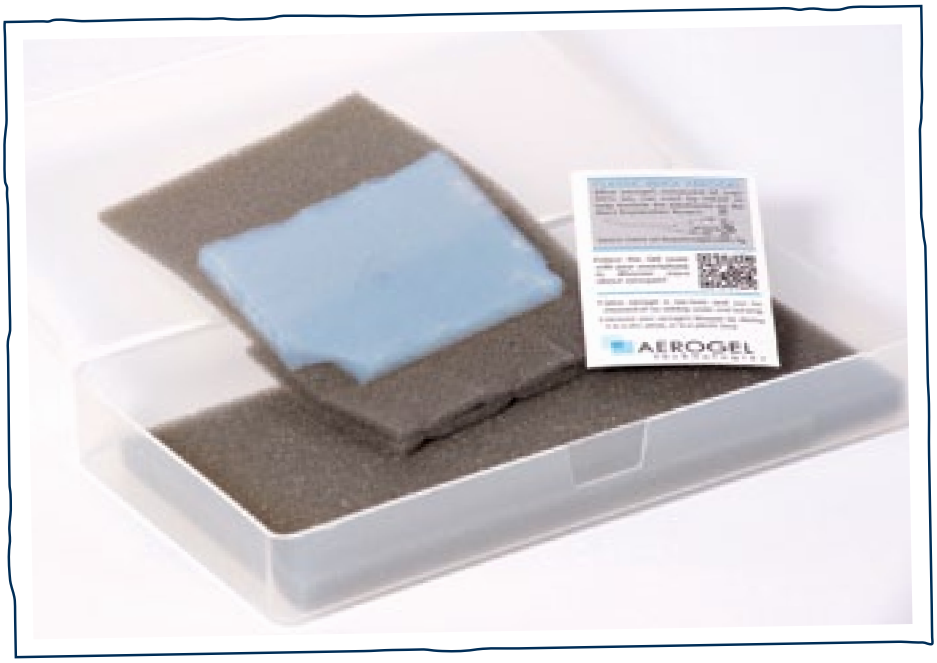
Applications

Please see the case studies for optics - this equipment is just used to demonstrate how waves travel.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 16



Aerogel

Overview

Aerogels are also known as 'frozen smoke' because of their translucent appearance. They are incredibly light, low density solid materials, composed of up to 99.98% air by volume. As a result they are excellent thermal insulators and have many applications throughout science and engineering, including in space.

How it works

The aerogel in this kit is a transparent, super-insulating silica aerogel. These aerogels have the lowest thermal conductivity of any solids known, meaning that very little heat energy is transferred through them.

1) Why is it called aerogel?

Aerogels begin life as a gel. However the liquid component of the gel is replaced by a gas causing it to have a very low density.

2) How is aerogel made?

The silica in the name refers to the oxide of silicon. It is the same base material that is used to make glass.

Aerogel begins life as a jelly like substance. This jelly has huge numbers of tiny pores where the liquid portion of the gel is held. In order to remove the liquid, but preserve the structure, the gel is 'super-critically' dried. In this process the gel is heated under pressure until a critical point is reached where the original liquid gel inside exists in both liquid and gas states. This allows the liquid to be slowly removed without damaging the structure of the gel. The resulting material has the structure of the original gel, but each pore is filled with gas rather than liquid so it has a very low density.

3) Why is it such a good thermal insulator?

Heat energy can be transferred within a medium by thermal conduction and thermal convection (the movement of gas and liquid molecules due to heating currents).The tiny air pockets in the aerogel are too small for convection to take place within - and since gases have relatively low density compared to solids, standard thermal conduction is also greatly reduced. This leads to the incredibly high thermal insulation properties of aerogels.

Experiments to try

The aerogel is EXTREMELY fragile and should be handled with great care. Please refer to the handling and storage instructions which can be found in the aerogel container.

1) Demonstrating insulation

The insulating ability of aerogel can be demonstrated by carefully placing it on top of a tripod. An ice cube or wax crayon can be placed on top of the aerogel and then heated with a blue Bunsen flame or blow torch. The ice/crayon will not readily melt. This experiment can then be repeated with another material, such as glass of a similar thickness and the rapid melting observed for comparison.

It is recommended that due to the fragile nature of the aerogel, this experiment should be filmed by the science centre to be used in shows or school sessions to preserve the aerogel.

2) Comparing density

Traditionally polystyrene is considered a very light, low density material. Place a piece of polystyrene on a set of sensitive scales and note down the mass. Repeat this process with the aerogel. The volume of the blocks can be calculated and using the formula:

density = mass/volume

The density of the two materials can then be calculated and compared.

Applications

One of the first uses of aerogel was in the Stardust mission. Launched in 1999 its principal mission was to approach a comet named Wild-2 and travel behind the comet. The craft was fitted with aerogel 'wings' that collected particles from the comet tail which were returned to Earth in 2006 in a collection capsule to be studied.

Much of the UK's research on this project was funded by STFC.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 17

Overview

Meteorites are fragments of rock and/or metal that fall to Earth from space. They are the oldest objects in the solar system, around 4.5 billion years old, and provide insight into the materials that made up our own planet.

Some questions to ask

1) What types of meteorites are there?

There are three main types of meteorite and they are classed according to the amount of iron they contain.

- Iron meteorites are almost completely metal and have the appearance of melted metal as a result of the heating that occurs as they enter the atmosphere of the Earth. They are thought to be the cores of asteroids that melted early in their history.
- Stony-iron meteorites are a combination of stone and iron in almost equal quantities. They have an attractive speckled appearance as a result.
- Stony meteorites have a relatively low amount of iron in them and are almost completely silicate based. The majority of meteorite falls are stony meteorites.

You have been provided with an Iron meteorite and a stony chondrite slice.

2) Where do meteorites come from?

Most meteorites are the leftover material from the formation of the Solar System – although some are fragments of asteroids that have been separated in collisions. Most of these asteroids lie in an orbit between Mars and Jupiter known as the asteroid belt.

A small number of rare meteorites come from the Moon and the planet Mars. These meteorites are much younger than those from asteroids, being just 2,500 million years old from the Moon, and 10.5 million years old from Mars. We know where they have come from because their composition matches lunar rock brought back from the Apollo missions to the Moon, and Martian rock samples analysed by various Mars landers including the Viking probes in 1976.

3) Why do they burn up in the atmosphere, and when does a meteoroid become a meteorite?

Meteoroids (rocks from space) enter the atmosphere at phenomenal speeds. Pulled towards the Earth by gravity, they are typically accelerated to speeds of over 11 km/s. As a meteoroid crashes through the atmosphere, it compresses the gases that build up in front of it, causing massive heating and sometimes engulfing the object in a spectacular envelope of superheated plasma – a meteor or 'shooting star'. If any fragments reach the ground, they are referred to as meteorites.

4) How dangerous are they?

Luckily for life on this planet, large meteorite impacts are rare. Most rocks that approach the Earth will either burn up in the atmosphere before they impact the ground, or will 'bounce off' the atmosphere. However, occasionally a meteorite does make it through to impact with our planet.

Most impacts are small scale, with only localised damage. However 50,000 years ago a relatively large iron-nickel meteorite smashed into the Arizona desert. Although only 30m across, it had a mass greater than an aircraft carrier (well over 100,000 tonnes) and on impact ejected and vapourised enough earth and rock to leave a crater that is 1.2 km across, 170 metres deep and known as Meteor Crater – the first such feature on Earth whose origin was accurately determined to have been due to an impact from space.

Large meteorites can cause effects on a global scale. Sixty-five million years ago an event occurred that coincided with the extinction of the dinosaurs. It has long been theorised that a comet or meteorite impact was responsible for, or at least contributed to, this extinction. Only since the development of large scale aerial and space surveying of the surface of the Earth have scientists have been able to locate an enormous crater in the Yucatán Peninsula in Mexico. The Chicxulub crater is over 180 km across and it is believed to be caused by a meteorite at least 10 km wide.

An impact of this size would have had global consequences. Material would have been thrown up into the atmosphere that may have blocked out the Sun for an extended period of time, potentially plunging the planet into an artificial winter. Earthquakes would have been caused by the huge energy of the impact. While it cannot be conclusively argued that a large meteorite impact was solely responsible for the demise of the dinosaurs, it certainly would have helped to contribute to it.

Experiments to try

1) Mass

How can someone become a meteorite hunter? And how can a meteorite be identified?

The first thing to check is the mass of the meteorite. Meteorites are very dense and so tend to be very heavy. A selection of rocks and meteorites can be presented to participants to analyse. The first test should be to compare the masses. This can either be done by simply holding the rocks in the hand and comparing how heavy they feel, or using a set of scales.

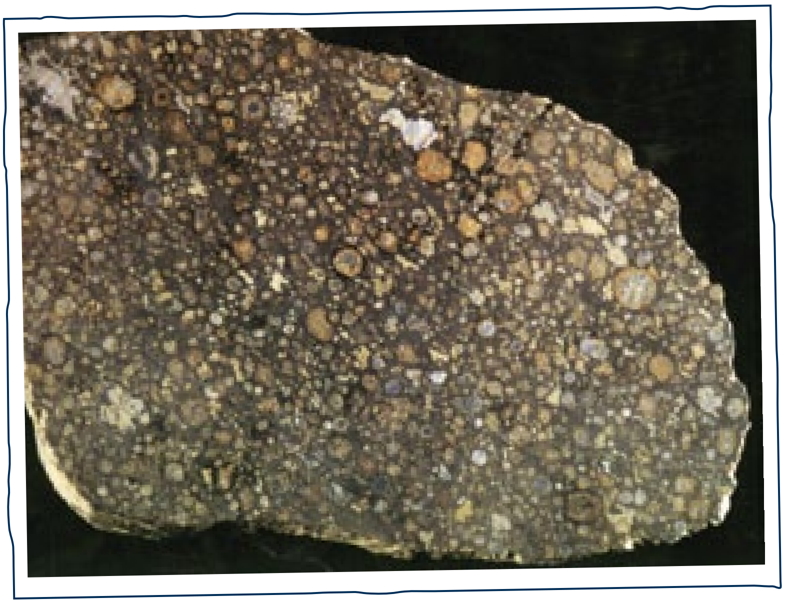
2) Visual inspection

Stony and stony-iron meteorites appear black on the outside. They are also smooth with a slight 'bobbling' on the outside. This is caused by the outer layer melting as it heats up during its journey through the atmosphere. The 'bobbling' is caused by gases trapped within the meteorite expanding as they get hotter and bubbling through the melted rock. We call this the fusion crust.

Similarly, iron meteorites get melted by the extreme temperatures of impact. They resemble a melted piece of metal and are usually black or a very dark metallic grey.

Lunar and Martian meteorites will also have a fusion crust, although these are harder to identify.

For meteorites that have a cut and polished cross-section it is possible to make a further visual inspection. Meteorites contain chondrules. These are small circular 'mini rocks' that are around a millimetre in size, contained within the structure of the meteorite, and represent the very first grains formed within our solar system.



In this image you can clearly see the small rounded chondrules.

3) Magnetism

Due to their iron content meteorites (apart from Lunar and Martian meteorites) are magnetic. Participants can be handed a magnet to explore which rocks present in front of them are magnetic or not.

Applications

Studying meteorites give us an insight into the formation of the solar system, as well as information on the geology of space and other planets. STFC funded researchers at the Open University's Planetary and Space Sciences Research Institute to examine these intriguing clues to the origins of our own planet.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Notes

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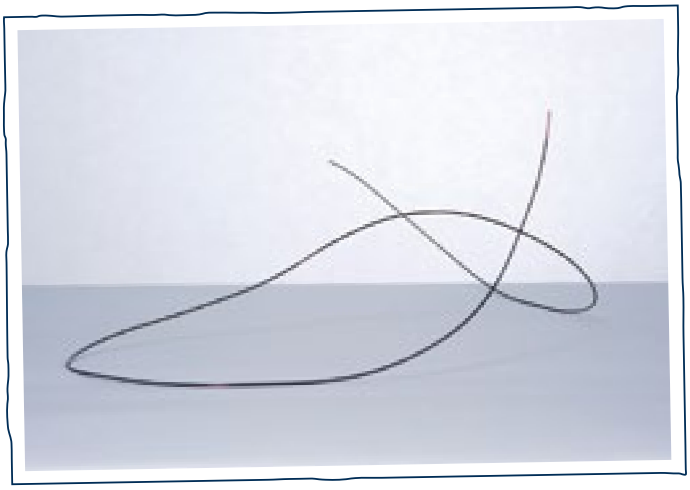


← Memory Metal

Overview

Memory metals 'remember' their original shape, returning to that shape when heated. They are a simpler, more reliable method for activities requiring a small, pre-set movement such as unfolding solar panels on spacecraft.

How it works

Memory metal is an alloy (a mixture of two materials that combines desirable characteristics from each material) of nickel and titanium. Memory metals can be mechanically deformed, but return to their original shape when heat is applied. The temperature at which this change occurs is determined by the ratio of nickel to titanium.

Most materials on Earth can exist in three phases: a solid phase, liquid phase and gas phase. Memory metal however has two different solid phases.

The first phase is called the austenite phase. In this phase the metal has a very rigid arrangement of atoms. In the second phase, called the martensite phase, the metal is much more malleable (able to be bent or pressed out of shape and hold this new shape).

While in this second phase, the metal can be manipulated into any desired shape. When heated, the metal changes phase into the rigid austenite phase, returning to its original shape.

1) What are the useful properties of metals?

Generally, metals have a high melting point because their atoms are held together by strong metallic bonds.

They have an abundance of free electrons (electrons that are not 'attached' to any particular atom) and as such these electrons can freely move through the material allowing them to be good conductors of electricity as well as good thermal conductors.

Metals also tend to be malleable, meaning that they can be easily bent or knocked into a different shape which will be retained.

2) What is electrical resistance in a metal?

Electrical resistance is the opposition to the passing of an electric current (flow of electrons) through a material. It is caused by electrons colliding with the atoms of the metal and so it becomes more difficult for the free electrons to pass through the material. It is measured in ohms. In materials with a high electrical resistance, the electrons comprising an electric current will lose higher amounts of energy whilst flowing through the material, which leads to a limit in the current flow when compared to materials with lower electrical resistance.

3) Why do metals warm up as electricity is passed through them?

The collisions between the free electrons and the atoms in the metal allow kinetic energy to be transferred to the atoms. As the atoms gain more energy, they vibrate more, allowing some of this energy to be converted to thermal (heat) energy. This causes the metal to heat up.

Extension: What will happen to the resistance of the metal if the atoms inside have more vibrational kinetic energy? This will make it even harder for the free electrons to travel through the metal, and as a result the resistance of the metal will increase with increasing temperature.

Experiments to try

1) Causing it to change shape

The memory metal has been 'pre-programmed' to be a straight wire. This means that when it is heated, it will return to the austenite phase adopting its rigid straight structure.

The memory metal should be bent into a shape, perhaps to spell out STFC. It can then be submerged in boiling water, and as the temperature of the memory metal increases the wire will straighten out. If you want to set your own shape you can do this with a candle or Bunsen burner – simply bend the wire whilst heating it, and then quickly cool it in icy water.

2) Demonstrating unfolding of solar panels

The memory metal can be bent over on itself, or even folded in a concertina style. To one end a 'solar panel' of card can be attached. If connected to a power source via a laboratory power pack (no more than 12V DC) the temperature of the wire will increase, causing it to unfold and deploy the 'solar panels'.

Applications

One of the most useful applications of memory metal for STFC has been in space science. Specifically, memory metals can be used in any mechanism that requires a movement between two set shapes.

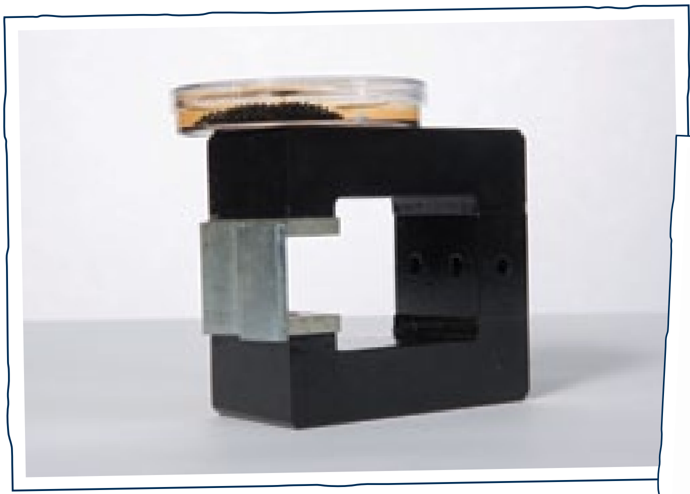
Memory metal can be 'reset' to return to any shape in its austenite phase by heating it to over 500 degrees Celsius and allowing it to cool slowly. This means that for future space telescope missions involving large arrays of mirrors which need to be unfurled to create one large diameter mirror, memory metals may be used to return the folded mirror configuration to a pre-determined shape necessary to create the single, large mirror.

This could be a much more reliable method than relying on a mechanical method for mirror deployment, as all that would be necessary for the shape change to occur is for a current to be passed through the wire.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 19



Overview

Ferrofluids become strongly magnetised in the presence of a magnetic field and give us a fantastic visual way to observe the magnetic fields around objects.

How it works

Ferrofluids contain ferromagnetic nano-particles (incredibly small particles of materials that are influenced by a magnetic field, such as that produced by a strong iron magnet). These nano-particles are suspended in a carrier fluid. When exposed to a magnetic field, peaks will form within the ferrofluid at points of high magnetic field strength. As a result, the peaks can be used to map magnetic field lines.

Unlike the traditional method of using iron filings on paper above a magnet to map the field lines, ferrofluids will only map the strongest regions of these lines before succumbing to gravitational forces.

1) What is a magnet?

A magnet is a material or object that produces a magnetic field. Magnets can be permanent (such as a bar magnet) or induced (such as an electromagnet). Magnets have a north and south pole, or pairs of N and S poles. No magnetic monopoles have ever been observed but the search continues in particle/high-energy physics experiments.

2) What is a magnetic field?

A magnetic field is the region of space where a magnetic force has influence. While we commonly associate magnetic fields with permanent magnets or electromagnets that can be switched on and off, magnetic fields are fundamentally created by the movement of charged particles, i.e. electric currents (usually electrons). This linkage exists because electric and magnetic fields are both part of the same fundamental force of Nature – the electromagnetic force.

A magnetic field can be represented by field lines showing the direction and relative strength of the magnetic field in a region of space. In these representations the density of field lines is a measure of the strength of a magnetic field in a given region.

Magnets have a north and a south pole or pairs of poles. The field lines run from North to South.

A North pole of one magnet will exert an attractive force on the South pole of another magnet.

In order to determine to what degree a magnet will attract or repel another magnet, the relative positions of the magnets' poles and the interactions between the field lines of the respective magnetic fields must be considered.

3) What do the peaks show?

The ferrofluid will peak in the regions where a magnetic field is strongest. The magnetic field has to be relatively strong for the magnetic force to overcome the force of gravity on the ferrous nano-particles.

Experiments to try

1) Observing a magnetic field

If a petri dish is filled to a level of a few millimetres it can serve as an excellent observation dish. When a strong magnet such as a neodymium magnet is placed under the petri dish, the peaks correlating to regions of maximal magnetic field strength can be easily observed.

2) Turning the magnet

If the magnet is turned, the orientation of the peaks will change as they follow the regions of greatest magnetic field strength.

3) Bar magnet and iron filings

The bar magnet supplied is a permanent magnet. This means that it will retain its magnetic field without the aid of an electric current for a very long time.

Bar magnets are usually made of ferromagnetic materials (elements that can naturally have a magnetic field). These include iron and nickel.

Each end of a bar magnet is considered a pole – one being north, the other south. When freely suspended, a bar magnet will act like a compass needle and align itself with the Magnetic North Pole of the Earth.

Ferromagnetic materials are not only used to make magnets, but they can be used to observe a magnetic field.

Place the bar magnet on top of the iron filings bubble (this is basically a closed plastic container filled with iron filings). The ferromagnetic iron will align itself with the magnetic field lines of the bar magnet allowing this field to be viewed.

Applications

At first glance ferrofluids may appear to be little more than a visualisation tool for magnetic fields. However they have many practical uses.

When used with a strong enough magnet, ferrofluids are extremely effective at reducing friction between the magnet being used and a surface. A coating of ferrofluid can actually allow the magnet to glide across a surface with minimal levels of mechanical resistance between the surfaces.

Ferrofluids are commonly used during MRI (Magnetic Resonance Imaging) and can even be used in detecting cancer.

Current research is exploring the possibility of using ferrofluid loops to help control the attitude (orientation) of spacecraft through interactions with controllable magnetic fields on the spacecraft that can be switched on and off.

Extra resources

For extra resources, videos, updates, and more, please visit the website
www.exploreyouruniverse.org

Equipment Briefing Sheet / 20

Levitating Magnets using Superconductors

Overview

Superconductors are materials which exhibit no electrical resistance. The flow of an electric current within a superconductor material will continue forever, with no loss of energy from the electrons as long as the material remains in the superconducting state.

The first superconductors were extremely difficult to use since they required cooling to just 4 degrees above absolute zero. Absolute zero is also known as zero Kelvin (0K)* and is equivalent to −273.15 °C.

In the mid 1980s a new family of superconducting materials was discovered including Yttrium Barium Copper oxide, which exhibited superconducting states at far higher temperatures of around 90K (-183 °C). These are known as HTSC (high temperature superconductors) and have many more applications since the 'critical temperature' (Tc) can be achieved using liquid nitrogen (boiling point 77K) is much cheaper and more readily available than the liquid helium (boiling point 4.2K) needed to cool classical low-temperature superconductors.

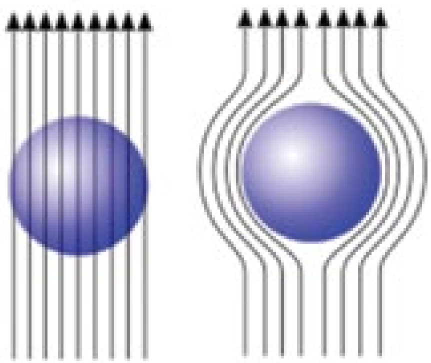
*The Kelvin is the primary unit of temperature measurement in the physical sciences and unlike the degree Celsius scale is not referred to (or typeset) as a degree.

Experiments to try

The two demonstrations are designed to show magnetic phenomena associated with superconductors which have direct applications to STFC-supported science.

1) Levitating magnets and the Meissner effect

Superconductors will exhibit what is known as the Meissner effect when in proximity to a weak magnetic field. The magnetic field will be expelled from the superconductor if the superconductor is cooled to below its critical temperature whilst in the magnetic field and so the superconductor will become a diamagnetic material (it will create a magnetic field in opposition to an externally applied magnetic field).



Temperature greater than critical temperature

Temperature less than critical temperature

This magnetic 'expulsion' means that a small magnet will 'levitate' above an yttrium barium copper oxide disc if it is cooled with liquid nitrogen to below its critical temperature.

Procedure

The HTSC disc (use the wider thinner one) is placed in the cooling container with a small rare earth magnet on top of it. There is no magnetic expulsion and so the magnet sits on the disc.

If liquid nitrogen is poured into the container so that it just covers the HTSC disc, the temperature of the disc will start dropping until it reaches 90K (-183°C). At this temperature the HTSC becomes superconducting, the magnetic flux (the component of the magnetic field created by the magnet) will be partially expelled from the disc and the result is a repulsive force which will levitate the magnet.

Whilst in this state, if tweezers are used to 'squeeze' the magnet closer to the disc, a repulsive force will be observed.

As long as the temperature remains below the critical temperature, the magnet will stay levitating – this can be aided by regular top-ups of small amounts of liquid nitrogen.

As the HTSC temperature rises above its critical temperature, the magnetic flux expulsion ceases, the material loses its diamagnetic effect and the small magnet will cease levitating.

It should be noted that for this demonstration, even with a small rare earth magnet as in the kits we actually get partial penetration of the magnet's magnetic flux into the HTSC disc. This means that the Meissner effect is not complete; however there is enough expulsion of flux to cause the levitating effect as long as the HTSC disc is below its critical temperature.

2) Strong levitation and frictionless superconductor magnetic bearings

In this demonstration we are not relying on the Meissner effect. In this case, rather than expelling the magnetic flux from the superconductor, it traps the strong magnetic flux within the superconductor. If we cool an HTSC disc (the thicker one with a slightly smaller diameter) below its critical temperature near a strong permanent magnet then the magnetic flux generated by the magnet gets trapped within the HTSC disc, leaving them magnetically linked or 'pinned'. Once this has happened, the disc and magnet will try to maintain their relative positions – even if the disc is moved away from the magnet with tweezers, the magnet will 'follow' and maintain the separation as long as the disc is still superconducting (i.e. below its critical temperature).

Once the HTSC disc is below its critical temperature and has a trapped amount of magnetic flux within it, then a flywheel can be placed on the levitating magnet and spun. It will keep spinning for several minutes, only losing energy through aerodynamic resistance forces produced because of airflow over the spinning flywheel rather than mechanical resistance forces in traditional bearings. This is the basis of superconducting magnetic bearings that are being developed for future energy storage systems.

Applications

Superconducting materials have a wide range of uses in accelerator science, astronomy and MRI applications.

Inside the Large Hadron Collider (LHC) at CERN, the particles are steered around the 27 km super-cooled racing tube by huge magnets. The combination of the high voltage needed to accelerate the particles and the strong field needed to conduct the electromagnets means that superconducting magnets are essential. Standard copper wires would just burn.

The Diamond Light Source in Harwell, Oxfordshire uses a strong magnetic field to produce the high-energy X-rays needed for experiments. Two of the X-Ray beams use superconducting magnet arrays called wigglers to produce very intense, high energy X-rays capable of penetrating deeper into materials.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 21

Van de Graaff generator

Overview

A Van de Graaff generator generates static electricity which can be used to investigate a number of phenomena, and formed the basis of the first ever particle accelerators.

How it works

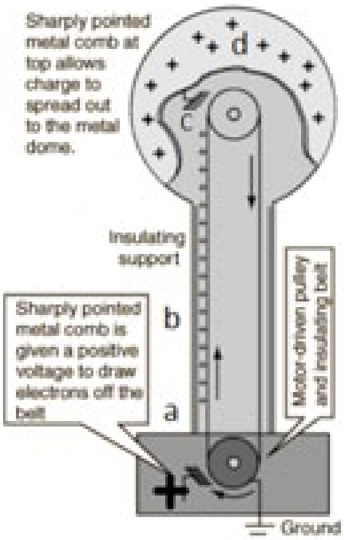
1) What is a magnet?

A magnet is a material or object that produces a magnetic field. Magnets can be permanent (such as a bar magnet) or induced (such as an electromagnet). Magnets have a north and south pole, or pairs of N and S poles. No magnetic monopoles have ever been observed but the search continues in particle/high-energy physics experiments.

2) What do we mean by a static shock and how is it generated?

Electrons (negative charges) are able to move. If you walk across a carpet, electrons move from the carpet to you. Now you have extra electrons and an overall negative static charge. Metal objects like door knobs are conductors so when you touch one, electrons can jump from you to the door knob, and you feel the static shock as the extra electrons picked up by you flow away into the door knob.

This most commonly happens in winter when the air is very dry. In summer when the air holds more moisture the water droplets allow a slow but steady escape of extra electrons from you to the surrounding air. However when the air is drier there are fewer conducting water droplets and as such a build-up of electrons can occur which will create a spark when they can finally overcome the distance between you and the door knob and jump across to it.



3) How does a Van de Graaff generator work?

a) A pulley drives an insulating belt across a sharply pointed metal comb in the base of the machine. This has been given a positive charge by a power supply.

b) Electrons are removed from the belt, leaving it positively charged. In fact, the metal comb **'scrapes'** electrons from the belt through a process called the triboelectric effect (caused by friction). For more details see www. exploreyouruniverse.org.

c) As the positively charged belt moves to the top of the apparatus it attracts electrons towards its. These come from the hollow metal dome at the top causing the dome to have a deficit of electrons.

d) This leaves the dome positively charged and creates a potential difference (also known as a voltage) on the Van de Graaff generator.

Charged particles create an electric field. With such a large build-up of positive charge on the dome, the Van de Graaff generator produces a large electric field.

Electric fields interact with charged particles. The strong electric field around the surface of the dome allows any charged particles within the vicinity of the dome to be accelerated/deflected from their normal position or trajectory. What actually happens will depend upon the location and circumstances of the charged particles concerned – the effects can range from the deflection of hair of a person close to the dome, to the 'glowing' of a fluorescent tube held near to the dome.

Please also see the Van de Graaff video (in the schools and masterclass presentations).

4) Why does hair 'stand on end' when the Van de Graaff generator is touched?

If a person touches the dome, the large positive charge on the surface attracts electrons from the person towards the dome leaving their extremities (such as their head) with an overall positive charge. Since like charges repel, the now positively charged hairs repel each other causing them to try to get as far apart as possible and the result is the hair 'stands on end'.

5) Why does the generator spark when a grounded metal sphere is brought close to it?

This is the same principal as any static shock. When a grounded (i.e. neutral) metal sphere is brought close to the dome, the large build-up of positive charge on the generator attracts electrons from the grounded sphere. The only way they can get to this positive charge is to cross the air barrier between the sphere and the dome. It is this flow of electrons that we see as the electrical spark. The spark appears blue because the predominant gas in the air is nitrogen.

Experiments to try

SAFETY NOTE: Before you use the generator please ensure that the smaller earthing sphere is plugged into the earth cable port on the generator. If you don't then there is a possibility that the second sphere starts off at a higher electrical potential than normal – and the result could be an electrical discharge between dome and sphere when least expected, or a small electric shock when someone touches the smaller earthing sphere. Earthing it by plugging into the earth cable port will ensure that it has lost any charge that might have accumulated during previous demonstrations/use.

No one with a pacemaker, hearing aid or underlying heart condition should touch the Van de Graaff generator or related apparatus, or be within 3 m when the generator is in use. This is because the charge accumulation and intense local electric field could disrupt the electronics in the hearing aid and pacemaker. It might also potentially have an effect on the heart although there have been no recorded incidents of this. Please refer to the Health and Safety section for more information.

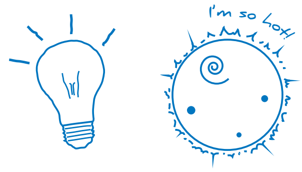
1) Making your hair stand on end

Participants must stand on an insulator, such as a plastic box. They must place their hands on the generator dome **BEFORE** the generator is turned on to avoid getting a static shock from the generator. Observers should stand at least 2 m away so as not to accidentally shock themselves from the participant.

Turn the machine on and allow sufficient positive charge to build up on the participant so that their hair stands on end. This takes about 10 to 30 seconds depending on atmospheric conditions and the individual physiological characteristics of the participant. When ready turn the generator off making sure that the participant's hands remain in contact with the dome (again to avoid the chance of a static shock which, although mild, is unpleasant).

Once the generator is turned off the participant should let go of the dome. Remaining on the insulating box, they should be handed a wooden metre ruler with the demonstrator holding the other end to allow the participant to discharge their positive charge slowly.

Once this has been completed they may carefully step back onto the floor.



2) Floating pie tins

Place a stack of foil pie tins on the top of the generator. When the generator is turned on, electrons in the pie tins will be attracted to the dome leaving the pie tins positively charged. This means that they will repel each other, and the sphere, and fly off.

3) Creating Sparks

While the generator is running, bring the earthed smaller metal sphere towards the top of the larger dome and watch as a spark flies between the two. To show that it is a form of energy a piece of thin paper can be placed between the two and a small hole will be burnt through. There is such a difference in charge between the positive sphere and the neutral metal earthed sphere that electrons are 'pulled' over to the Van de Graaff. If the smaller sphere is held around 3 cm from the larger dome, a series of small sparks is observed. Why is this? It takes time for a large enough positive charge to build up between sparks in order to initiate the next discharge (spark). This can also be thought of in terms of the electrons that have jumped onto the sphere need to be carried away by the belt.

4) Bringing a strip light close to the generator

SAFETY Note: The metal terminals of the strip light should not be touched when doing this experiment.

The terminals of the light should always be well wrapped in electrical insulating tape. Touching the terminals of the light will give you a mild electric shock.

As the strip light is brought towards the generator dome, it will light up with no need for physical contact with the dome.

This is caused by the electric field surrounding the generator exciting electrons of the mercury vapour within the strip light tube To lose energy these electrons give out small packets of light energy called photons that are of too high a frequency for the human eye to see (they are generally UV). These photons produced from the mercury vapour can then strike the fluorescent coating of the tube, exciting electrons in these atoms. To lose energy these electrons release photons, but this time the photons are lower energy visible photons that we can see. Hence the tube appears to light up. Richard Box, the artist-in-residence at Bristol University's physics department, used this phenomenon to astounding effect in his 'field' installation. He installed 1301 fluorescent tubes under some overhead power lines, in a farmer's field, and watched them light up powered only by the electric fields generated by the power lines.

Applications

STFC is heavily involved in particle physics research working with several different types of particle accelerator, all of which accelerate particles to very high energies. These have applications such as exploring materials, examining what constitutes matter and investigating what gives us mass. The Nuclear Structure Facility (NSF) at STFC Daresbury Laboratory was an excellent example of Van de Graaff generators serving a particle accelerating purpose. Proposed in the 1970s, commissioned in 1981 and opened for experiments in 1983, it consisted of a tandem Van de Graaff generator operating routinely at 20 MV (20 million volts), housed in a distinctive building 70 metres high. During its lifetime the NSF accelerated 80 different ion beams for experimental use. The ion beams in use ranged from protons to uranium ions. It was decommisioned in 1992.

Modern particle accelerators now use energies far higher than this. The Large Hadron Collider (LHC), near Geneva, for example will use beams with 7,000,000,000,000eV through the use of strong electric and magnetic fields to accelerate and deflect charged particles.

Why don't they use a giant Van de Graaff generator in modern particle accelerators?

When using static electricity it is very difficult to prevent sparks occurring. This not only wastes energy, but is also very dangerous. Even though the air is quite resistant to conducting charge, at high enough voltages the object has charges with enough energy to partially ionise the air (to 'steal' electrons from the molecules in the air) allowing them to conduct electricity. For warm, dry air this 'breakdown voltage' is about 30,000 V/cm. That is, when holding a voltage of 30,000V, the air can break down and create a spark of around 1 cm. This means that if we were to use a giant Van de Graaff generator for the large particle accelerator such as the Diamond Light Source, near Oxford, the sparks would be incredibly large. With such a large electric field being generated, it would be too unpredictable and too dangerous to use.

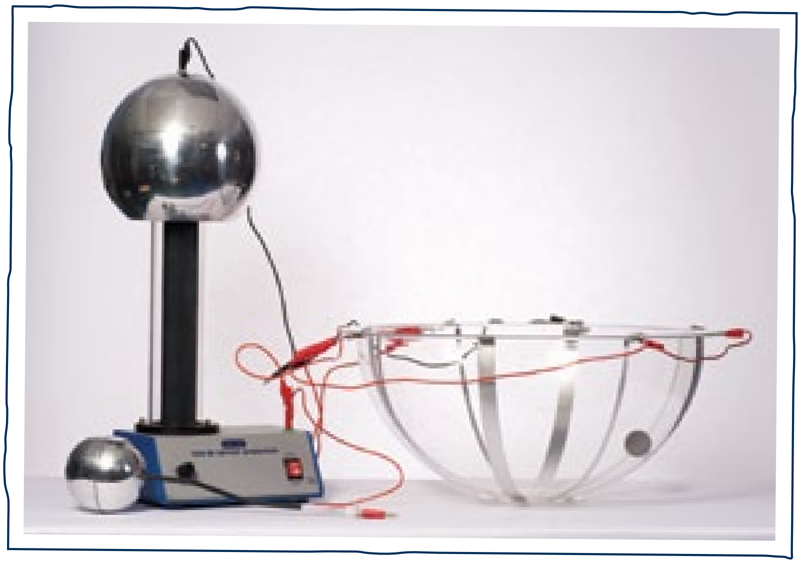
However particle accelerators all began with the Van de Graaff generator, and through those early experiments with static electricity, accelerating charges and building bigger and bigger voltages, the science of particle physics began.

For examples of other particle accelerators please see Salad Bowl Particle Accelerator Briefing Sheet.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 22



Salad Bowl Particle Accelerator

Overview

The Salad Bowl particle accelerator demonstrates how one of the earliest forms of particle accelerator, the cyclotron, works. The ball that represents the particle is covered in metallic paint. The Van de Graaf generator supplies a voltage to the metal strips, which in turn charge the ball. When the ball becomes charged it is repelled from the metal strips. The ball discharges whenever it crosses an earthed strip.

How it works

1) Are the voltages on the metal strips constant?

Yes. The strips that cross in the centre of the bowl are at about 30kV and the other strips are earthed at 0V. This isn't as dangerous as it sounds though, since only a very small current can flow.

2) How do these voltages accelerate the ball?

A ping pong ball coated in a conducting paint is placed in the bowl. When the Van der Graaff is switched on, the ball moves around a little because of induced charges on the ball. Soon it comes into contact with a charged strip and picks up that charge – so now it has a charge that is identical to that of the strip. Charges that are the same ('like charges') repel each other, so this gives the ball a push along. When the ball rolls over a grounded strip, the ball loses its charge. However, it doesn't lose its momentum and keeps rolling around the bowl. The next time it comes across a charged strip, it picks up the charge again, gets repelled in the same direction as before and once again gets a little kick along. Every time the ball crosses a charged strip it gets accelerated.

3) Will the ball keep accelerating forever?

No, not in the equipment you have. As the ball gets accelerated it climbs the wall of the salad bowl. However, gravity is trying to pull the ball back down again. Once the accelerating force of the strips is equal to gravity the ball will find a steady state and keep moving around the bowl.

4) What happens to particles in real particle accelerators?

The particles in real particle accelerators of this type (cyclotrons) do not have a wall of a salad bowl to climb. They just circulate inside a tube. The particles are accelerated by a Radio Frequency (RF) voltage. As the particles are accelerated more and more the radius of their orbit increases (just as the radius increases as it climbs the wall of the salad bowl). Eventually their radius becomes too large and they are lost.

5) So is it possible to keep particles inside particle accelerators?

Yes, it is, although it is not possible to keep them for long in a cyclotron. Particles that need to be stored for long periods are stored in a type of accelerator called a synchrotron. Synchrotrons have magnetic fields (for steering the particles) that increase as the energy of the particles increases. This keeps them on the same path. Cyclotrons, in contrast, have fixed magnetic fields and so the path of the particle is a circle with ever increasing radius (a spiral).

6) How does the voltage in a real particle accelerator differ from this model?

The difference is that in most modern accelerators the voltage isn't static like the one from a Van de Graaff generator. You might have noticed that in this demonstration the 'particle' is changing its charge every time it gets a kick. But real particles have a fixed electric charge, so instead the voltage has to change very quickly from positive to negative and back again. That way, every time the particle goes past it will see an accelerating voltage rather than a decelerating one! To do this, we use radiofrequency cavities. These cavities resonate with electromagnetic waves and play the trick of providing a rapidly varying voltage. If the frequency of the wave is timed correctly, every time the particle goes through it will be accelerated.

Method

1) Attach the high voltage cable from the Van de Graaff generator to the set of metal strips that cross in the middle and the earth cable to the other set of strips.

2) Place the metallic ball in the bottom of the bowl.

3) Switch on the Van de Graaff generator and watch to see if the ball starts to move.

4) If it doesn't you may need to give the bowl a slight nudge (don't touch the metal strips while doing this).

5) Watch the ball circulate.

6) To end the demonstration either:

- Pick up the ball just after it has crossed an earthed strip (this is quite hard) and then switch the Van de Graaff generator off and discharge it, or
- Just switch the Van de Graff generator off and discharge everything with the discharging sphere before touching anything

Applications

Both cyclotrons and synchrotrons have many uses.

Modern accelerators include a type of accelerator called an FFAG (Fixed Field Alternating Gradient). This is neither a synchrotron nor a cyclotron but yet another sort of accelerator. It does have some things in common with both sorts of accelerator though. There is a prototype FFAG at STFC Daresbury Laboratory called EMMA.

FFAGs can be used for medical purposes, such as a method called boron neutron capture therapy. A beam of neutrons is directed at a cancer tumour which has been administered with a non-radioactive Boron isotope – the Boron isotope is stimulated to undergo nuclear fission, releasing alpha particles that then specifically kill (cancerous) cells in the surrounding area. They are also being investigated as a new way of running nuclear reactors in a safer way.

Synchrotrons are often used as particle accelerator Light Sources (such as the Diamond Light Source). These light sources produce synchrotron radiation over a wide range ranging from infrared to X-rays. This 'light' can be used to study the structure of things at the molecular and atomic level. The Diamond Storage Ring doesn't accelerate (increase the energy) of particles, but its Booster accelerator does.

The largest and most famous accelerator in the world, the Large Hadron Collider at CERN is also a synchrotron, although a rather large and complex one! The protons for the LHC go through a series of linear accelerators and synchrotrons before reaching the LHC, which then accelerates them up to top energy before going into 'storage mode' in exactly the same way as a synchrotron light source. Unlike a light source, the LHC has two beam pipes and two beams travelling in opposite directions. Once in 'storage mode' the operators are able to direct the beams to collide when an experiment requires this.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 23

Plasma Ball

Overview

The Plasma Ball is a spectacular way to observe the interaction of electric fields and charged particles. The physics behind the effects observed can help to explain phenomena such as the Aurorae (The Northern and Southern Lights).

How it works

1) What is a plasma?

A Plasma is a hot, ionised gas and is made up of ions.

An ion is an atom or molecule where the total number of electrons (negative charge carriers in orbit around the nucleus of an atom) is not equal to the total number of protons (positive charge carries in the nucleus of an atom), giving it an overall positive or negative electrical charge.

2) What makes up the plasma ball?

At the centre of the plasma ball there is a small spherical electrode. It is encased by a larger glass ball and between the two is a very low pressure gas. This gas has to be very unreactive (or inert) otherwise it would react with the electrode and damage it.

3) What happens when it is switched on?

When the plasma ball is turned on, the electrode builds up a high voltage, high frequency current (flow of electrons). This current is an alternating current, meaning that the current constantly changes direction. This means the electric field produced also changes direction. We sometimes refer to this as 'oscillating'. Electric fields interact with charged particles. As electrons leave the electrode they are accelerated by this field. As they are accelerated they gain energy and can 'bash' into the gas atoms/molecules in the ball.

If they do this with enough energy, they can ionise the atoms/molecules (strip electrons from the atom/molecules) and this causes a hot ionised gas called 'plasma' to be formed.

The gas used in your plasma ball is Argon.

4) Why do I see tendrils?

As the high energy electrons move through the gas they have a chance of collision with the gas atoms/molecules. If there is a collision, energy is transferred into the gas. This excess energy is then released in the form of a 'photon', an individual 'bundle' of light energy that sometimes behaves as if it were a particle but without any mass. This photon takes away the excess energy returning the gas atom/molecule to its original state. As the electron moves through it will collide with a line of gas atoms/molecules. This line is then visible as our eye detects the photons that are being emitted.

5) What determines the colour of the tendrils?

The colour of the tendril or plasma streams is determined by the element that is used as the gas in the plasma ball sphere. Different gases will absorb different amounts of energy.

This means that the photons emitted will have different amounts of energy. The energy of a photon is directly linked to its frequency. As such, photons of different energy have different frequencies, which the human eye perceives as different colours.

Experiments to try

1) Touching the plasma ball

When you touch the glass sphere of the plasma ball, a single bright tendril flows towards your finger. Even with the glass in the way, the finger, being attached to a person who is standing on the floor (earthed) is providing a path for the charge to flow down to the earth. The area around the finger gets warm because we have a transfer of electrical energy to thermal energy.

2) Lighting a fluorescent strip light without touching the ball

SAFETY NOTE: The terminals at the end of the strip light must first be wrapped with insulating electrical tape to prevent a shock being experienced.

When a fluorescent strip light is brought close to the plasma ball it will light up without needing any contact with the ball itself.

The fluorescent light is full of vapour and the electrons in this vapour become excited by the very strong oscillating electric field. This means that electrons in the vapour can gain energy. As those electrons lose energy we get photons given out, and some of those photons are high energy ultra violet light. These photons interact with the strip light coating producing the light we see.

3) Pull the light further from the globe

As you move the fluorescent light further from the plasma ball, the light emitted gets dimmer. This is because the strength of the oscillating electric field experienced by the tube gets weaker as the tube is moved further away from the source. The further away the light is, the less energy can be gained by the electrons and a fewer number of interactions take place.

4) Making a coin spark

If you place a 2p coin on the top of the plasma ball, it is possible to bring a second 2p coin a short distance (less than a millimetres) above the ball and observe a spark of electricity passing between the coins. This second coin should be held in an insulated retort stand or held with electrically insulating gloves (e.g. rubber gloves).

The coin on the plasma ball, being a metal, has lots of free electrons which can be influenced by electric fields. The electric field from the plasma ball causes the electrons to build up on the surface of the coin.

When a second 2p coin is brought towards the first, electrons on the surface discharge onto the second coin. If a piece of paper is placed between the two coins you can see the tiny burn marks that are left behind – another example of how electrical energy can be transferred to thermal (heat) energy.

Applications

Although plasma physics is not widely discussed by the general UK public, understanding how plasmas work and interact with lasers and matter is very important.

STFC supports the Vulcan High Power Laser based at the Central Laser Facility in Oxfordshire. Vulcan is a world leading ultra-high power laser system used to study laser plasma interactions such as fusion energy.

The principal behind fusion energy involves igniting a dense plasma with high energy photons produced by a laser to induce the fusion of atoms (when two atoms are smashed together to form a bigger atom). This is the same process that powers the Sun, and could in theory revolutionise energy production.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Notes

Equipment Briefing Sheet / 24

Liquid Nitrogen

(inc Dewars and tipping trolley)

Overview

Liquid Nitrogen is Nitrogen gas, which makes up 78% of our atmosphere, which has been cooled until it turns into a liquid. The boiling point of liquid Nitrogen is -196°C and the liquid in the Dewar will be at or near this temperature. Liquid Nitrogen can be used to show how the properties of materials change at low temperatures.

A large 25 litre dewar is supplied to store the Liquid Nitrogen in. It is recommended that for demonstrations a small amount of Liquid Nitrogen is decanted into the smaller flask using the tipping trolley.

How it works

1) Why does liquid Nitrogen change the properties of materials?

As any material gets colder the atoms and molecules of which it is made lose more and more energy, move less and move closer together. This change in position and movement causes the material properties to change.

2) Why do I need to store liquid Nitrogen in a dewar?

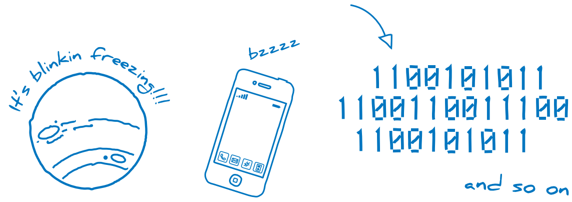
The boiling point of liquid Nitrogen is -196°C. If the liquid Nitrogen is exposed to temperatures higher than this it will boil and turn back into a gas. Therefore, it needs to be stored in a very well insulated container to keep it a liquid. The dewar has a special lid to allow for expansion. Never put it in a air tight container, it will explode.

3) What protective equipment do I need?

It is recommended that you wear gloves and safety goggles when pouring liquid Nitrogen from the large to small flask. You should also be wearing proper shoes (not sandals). When doing the experiments with liquid Nitrogen, gloves are necessary if you touch something which has been placed in liquid Nitrogen. Safety goggles are recommended at all times.

4) What should I do if I accidently splash liquid Nitrogen on myself?

If you splash a small amount of liquid Nitrogen on your skin it probably won't do much harm. If it doesn't hurt then no action is required. The liquid has just turned to gas. If you spill a significant amount on yourself or get it in your eyes then medical attention should be sought.



Experiments to try

1) Put a balloon filled with Helium or just normal air in a bowl of liquid Nitrogen. The balloon will shrink and sink. It will re-inflate when returned to normal temperatures.

2) Put a flower with reasonable size petals (e.g. a rose) in the liquid Nitrogen. When you take it out you will be able to crush the head and turn it to powder with your hand.

3) Put a glow stick which has been activated into the liquid Nitrogen. When placed in the liquid Nitrogen it will stop glowing. Once removed and it warms back up it will start glowing again.

4) Put a raw egg into a frying pan and pour liquid Nitrogen onto it. It will start to look like it is cooked. As it warms back up it will turn back to looking like a raw egg.

5) Put a small amount of liquid Nitrogen in a Pringles tube (or other similar container) and put the lid on. The liquid will turn to gas which will make the lid pop off.

6) Dip some rubber tubing in liquid Nitrogen and hold it there for about 10 seconds. Once removed it should break easily by snapping it or stamping on it.

Applications

Liquid Nitrogen and other cryogens, such as liquid Helium, have many uses in STFC research.

Liquid Helium is used to cool the receivers on radio telescopes such as the Lovell telescope at Jodrell Bank. The receiver is cooled to around -260°C. This low temperature reduces the noise in the electronics and allows much fainter signals to be detected from space than would be detectable otherwise.

Liquid Nitrogen and other cryogens such as Liquid Helium (boiling point -269°C, only 4°C above the coldest possible temperature) are also used in particle accelerators to create superconducting magnets. Electromagnets (coils of wire with current running through them) are used to steer charged particle beams. At high energy (such as the energy of the LHC) the magnetic field required to steer the beam through the required angle is very large. To get a large magnetic field you need a large current in the wire. However, the resistance of the wire limits the current which can be obtained in the wire. By cooling the wire the resistance is decreased and eventually becomes zero at very low temperature. This allows a high current to be able to run through the wire to create a strong enough magnetic field to steer the charged particle beam.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Equipment Briefing Sheet / 25

Cloud Chamber

Overview

A cloud chamber allows us to observe tiny particles and radiation that we normally cannot see with the naked eye. Its use provides an excellent springboard into discussions of particle physics and what makes up matter.

How it works

Here are some questions to help investigate how the cloud chamber works:

1) What is matter made from?

All 'ordinary matter' in the Universe (as opposed to 'dark matter') is made up from atoms, whether it is solid, liquid, gas or plasma. Atoms themselves are made up of three constituents – protons, neutrons and electrons. Protons and neutrons are in the nucleus at the centre of an atom, and the much smaller electrons orbit the nucleus at a relatively great distance. For example, if the nucleus of a hydrogen atom was 10 cm across, the electron would orbit at a distance of over 5 km. This shows very clearly that the majority of an atom is, in fact, empty space.

2) What types of nuclear radiation are there?

There are three main types of nuclear radiation, alpha, beta and gamma. They all have different properties but are all originally created in the nucleus of an atom.

Alpha radiation travels as particles, with an alpha particle consisting of two protons and two neutrons bound together. It is effectively a helium nucleus. Beta radiation consists of high energy, high speed electrons emitted from an atomic nucleus, and gamma radiation is a high energy electromagnetic wave emitted during energy changes within a nucleus.

3) Why are these forms of radiation dangerous?

All three types of radiation are ionising, meaning they have the ability to strip electrons from atoms. This can damage atoms in our body.

However they all behave in different ways:

Alpha particles are the largest type of nuclear radiation (in terms of mass), the slowest moving and have a positive charge. This means that an alpha particle can easily ionise many other atoms and lose a lot of energy in the process. As a result of the high number of interactions and relatively slow speed, alpha particles cannot travel very far in a material, and can actually be blocked by a sheet of paper.

Beta particles are smaller particles, with a negative charge and much higher velocity than alpha particles. They cannot ionise atoms as easily as alpha particles, and as a result can travel further through a material. This means that they need a few centimetres of metal to block them effectively, rather than a few sheets of paper.

Gamma radiation is very high energy and moves at the speed of light, but has the lowest ionising ability of all three types of radiation. This means it can make it through large widths of concrete and requires thick lead to block it.

4) How can radiation be seen?

Radiation cannot be seen directly. The cloud chamber is a type of nuclear radiation detector allowing observers to see the interactions of nuclear radiation with a cloud of alcohol vapour.

5) How does a cloud chamber work?

The felt at the top of the cloud chamber is soaked with either ethanol or propan-2-ol (isopropanol). This is very volatile and so will quickly form a vapour at the top of the cloud chamber. The cloud chamber is placed on top of 'dry ice' – frozen carbon dioxide (at -78°C). As the ethanol/isopropanol vapour falls it cools rapidly thanks to the dry ice. The ethanol/isopropanol wants to condense into a liquid at this temperature, but there is nothing for it to condense onto. This means that the air becomes 'super-saturated' or heavy with alcohol molecules.

If a charged particle, (such as an alpha particle produced as a result of radioactive decay) passes through the chamber, the isopropanol/ethanol molecules condense along the path (looking in appearance like the condensation trails behind an aircraft).*

The condensed droplets become small white streaks showing the path that the particle has taken.

* For a higher level of understanding, the charged particle causes the isopropanol/ethanol molecules to become electrically polarised and therefore attracted to the charged particle, and one another. It is actually this effect that causes the condensation process so vital to the function of the cloud chamber.

6) What is meant by radioactive decay?

The nuclei of some isotopes (variants of a particular chemical element with the same number of protons but a different number of neutrons) are unstable. They can split up or 'decay' releasing radiation, and do so in order to attain a more energetically stable state. Such isotopes are called radioactive isotopes or radioisotopes. When a radioactive isotope decays through alpha or beta emission it forms a different atomic element with a different number of protons. During/after this process, gamma radiation may also be emitted as the new 'daughter' nucleus stabilises.

Different radioactive decay routes may be available for a given radioisotope – these are referred to as different modes of decay.

7) What is the half-life of an isotope?

The half-life of a radioactive isotope is the time it takes for the number of nuclei of the isotope in a sample to halve by a given mode of radioactive decay.

Experiments to try

SAFETY NOTE: When using the cloud chamber insulated gloves should always be worn when handling dry ice.

1) Setting up the cloud chamber

Using a pipette, the felt at the top of the tank should be soaked with around 10 ml of alcohol (isopropanol or ethanol). The radioactive source should be placed on the black laminated card on the tray.

The tank should be upturned and placed in the centre of the tray. The cloud chamber should then be sealed at the bottom with blue tack or plasticine.

The tray should then be placed on to dry ice sitting in a plastic or polystyrene tray. The depth of dry ice should be at least 1 cm.

The LED strip lights should be placed on either side of the tank and the whole set up left to settle for 5-10 minutes. Once a super-saturated alcohol layer has formed, particle trails should be visible from the source.

2) Thoriated tungsten welding rods

These rods contain an isotope of Thorium called Thorium–232. This isotope decays through alpha decay and has a half-life of 1.405×10^{10} years (14 billion years). This is more than three times the age of the Earth and so there is still more than half of all the Thorium-232 that has ever existed naturally on Earth remaining.

As these nuclei decay, the paths of the alpha particles emitted can be seen in the cloud chamber by the long vapour trails that are left behind.

3) Stopping alpha radiation

If one of the thoriated tungsten rods is wrapped in a layer of paper, then there will be no vapour trails from that rod. This is because the alpha particles are so ionising within the paper that they lose all of their energy and do not emerge from it.

Applications

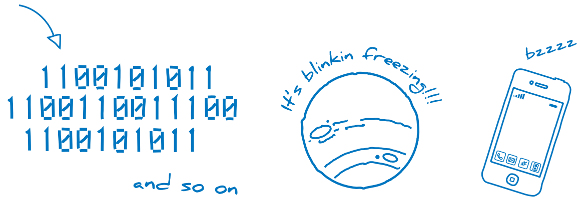
Particle physics is a major focus of STFC. From particle accelerators, to underground detectors, understanding the interactions of tiny particles that cannot be seen with the naked eye is vitally important to advancing knowledge of the Universe.

In addition to particle accelerators which are covered in some detail in the salad bowl particle accelerator briefing sheet, another STFC project involving detecting particles is the Boulby Underground Laboratory. Located 1100 m below ground at the bottom of an abandoned mine in North-East England, this facility focuses on detecting and understanding phenomena that are usually impossible to observe due to background radiation and interference.

Studies underway at Boulby range from the search for 'dark matter' in the Universe (the hypothetical matter that is thought to account for a large part of the total mass in the Universe), to studies of cosmic rays and radioactivity in the environment.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org



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and so on
It's blinkin freezing!!!
bzzzz

Notes

Equipment Briefing Sheet / 26

Scale Model of the Solar System

Overview

A set of spherical objects can be used to represent the planets in the Solar System. The sizes of the balls in this example are to scale. The planets in the Solar System vary significantly in size, as do the balls. It is also possible to do a scale model of the distances between the planets, but this would need to be on a different scale because of the vast distances involved. A suggested scale is included below. However, other scales can be used if this is appropriate to the size of your room etc.

How it works

1) Why isn't there a ball for the Sun?

If a ball for the Sun was included using this scale it would be 5.5 m in diameter! You could try using orange/yellow card cut to size.

2) Why are there only 8 planet balls?

There are only 8 planets. Pluto was originally the 9th planet but it was declassified as a planet in 2006. This is because another object called Eris was found in 2005 which is even further from the Sun than Pluto, but is bigger than Pluto. In fact Pluto is also smaller than our own Moon. Astronomers therefore decided that both Pluto and Eris were too small to be classified as planets. They were both classified as dwarf planets in 2006.

3) Why isn't there a ball for the Moon?

The Moon is not a planet and so is not included in the set of balls.

4) How far from the Sun would the planets be on this scale?

The following table (overleaf) shows these figures:

Planet/solar system object	Scaled diameter	Suggested type of ball	Scaled radius of orbit (distance from Sun)
Sun	5.5 m	None	0
Mercury	1.9 cm	Marble	229 m
Venus	4.8 cm	Bouncy ball	427 m
Earth	5 cm	Bouncy ball	591 m
Mars	2.7 cm	Smaller bouncy ball	900 m
Jupiter	56 cm	Gym ball	3.1 km
Saturn	46 cm	Gym ball	5.6 km
Uranus	19 cm	Football	11.3 km
Neptune	18 cm	Football	17.8 km

5) How far is it from the Earth to the Moon on this scale?

About 10 m.

6) How far is it really to the Moon?

About 250,000 miles.

7) Why haven't people travelled any further than the Moon?

It takes a few days to get to the Moon using current rocket technology. It would take most of a year to get to Mars, the next planet to us. It would take 20-30 years to reach the outer planets in the Solar System.

Experiments to try

1) Get people to guess how big Jupiter is if you show them the Earth model. You can give them all the other balls to choose from.

2) Get people to guess the distance to the Moon using this scale.

3) Choose other planet sizes and distances and see if anyone can guess these.

Extra resources

For extra resources, videos, updates, and more, please visit the website www.exploreyouruniverse.org

Health and Safety Guidelines

Liquid nitrogen

- Always wear proper shoes (not sandals) and clothes that cover as much of your skin as possible when handling liquid nitrogen.
- Wear safety goggles when handling liquid nitrogen.
- Wear gloves when handling objects which have been placed in liquid nitrogen.
- Gloves should always be worn if coming into direct contact with liquid nitrogen. However, if care is taken to use appropriately insulated vessels and the use of gloves will limit dexterity to the point that you are more likely to cause a spillage, glove use is at your own discretion.
- Store large quantities of liquid nitrogen in an appropriate vessel within an extremely well ventilated area, ideally outside if possible.

Lasers

- Never shine a laser in anyone's eyes.
- Always ensure the path of a laser beam cannot hit a person – be particularly careful when using prisms or diffraction gratings with lasers.
- Keep lasers fixed to a surface with the laser beam path away from the audience wherever possible.

Van de Graaff generator

- Ensure anyone with a heart defect, pacemaker, cochlea implant or any other metallic insert in their body keeps at least 4m from the Van de Graaff generator.
- Never touch the Van de Graaff generator unless you are sure it has been discharged.
- Always discharge the Van de Graaff and anything it has been connected to after it has been used.
- Always make sure anyone touching the Van de Graaff generator for demonstration purposes is standing on an insulated box.
- The Van de Graaff generator will induce an electric shock if a person is not discharged properly. When the demonstration involving touching the Van de Graaff is complete, turn off the generator, get the volunteer to remove their hand, and pass them the end of a wooden metre ruler. This will allow them to discharge slowly and safely.
- The shock the Van de Graaff can induce is not dangerous, but can cause alarm and some discomfort.
- If using the lighting tubes with the Van de Graaff, ensure you do not touch the metal contacts as you may receive a shock.

Salad Bowl particle accelerator

- Always discharge the metallic strips and ball after use.
- Never touch the metallic strips or ball while the Van de Graaff generator is switched on or before it has been discharged.

Solar telescope

- NEVER look at the sun apart from through the solar telescope.
- Always make it very clear to the audience that the solar telescope has a special filter to protect their eyes, and that looking at the Sun with any other optical device, including binoculars or ordinary telescopes, can lead to blindness.

UV lamp and diodes

- Do not look directly at the UV lamp as it is very high energy radiation and can damage the retina.
- Do not expose it to any part of your body for any length of time.
- Ensure tight time limits on use for students (maximum of 5 minutes for the diode activity).

For more information on the health and safety regarding any of the equipment and activities in this programme, please refer to the CLEAPSS website. Your organisation will be signed up as a CLEAPSS member (for English centres) as part of the programme, giving you access to all of their risk assessments (which are continually updated) and a hotline for advice on any new activities you may develop. Your centre will be given a username and password.

www.cleapss.org.uk/

Scottish centres can receive similar support from SSERC (of which they are already members).

EXPLORE YOUR UNIVERSE

Suppliers List

Our List of Suppliers

Description	Website	Supplier
Infrared source - remote control Laser pointer - red 12" T5 8W white fluorescent tube LED inspection lights* Fish tank* Black felt* Web camera	www.amazon.co.uk	Amazon
iPad3, 64gb, wifi only iPad camera connector kit iPad VGA adaptor cable	www.apple.com/uk	Apple
Ping pong balls**	www.argos.co.uk	Argos
Graphite		Local Art Store
Aluminium tray*	www.asda.com	ASDA
Aerogel	www.aerogeltechnologies.com	Aerogel Technologies
Superconductor kits	www.can-superconductors.com	CanSuperconductors
Ferrofluid	www.curiousminds.co.uk	Curious Minds
Solar telescope camera	www.spacecentre.co.uk	Made bespoke by Jeff Lashley at the National Space Centre
Aluminium tape** Plasma ball	www.maplin.co.uk	Maplin
Van de Graaff generator**	www.newtonresources.co.uk	Newton Resources
FLIR E30 thermal imaging camera	www.pat-services.co.uk	PASS Ltd
Spectroscopes	www.patonhawksley.co.uk	Paton Hawksley

*items required to make your own cloud chamber **items required to make the 'salad bowl' particle accelerator

More

Description	Website	Supplier
UV lamp	www.philipharris.co.uk	Phillip Harris
Laser optics kit		
White light accessory kit		
White LED light source		
Iron filings bubbles		
Diffraction grating slide		
Nickel spray	uk.rs-online.com	RS-online
Iron meteorites	www.geodes-etc.co	Geodes, etc
Stony meteorites	bigkahuna-meteorites.com	Big Kahuna Meteorites
Salad bowl accelerator	www.sunlightplastics.co.uk	Sunlight Plastics
Spectral tube holder and power pack	www.timstar.co.uk	Timstar
Spectral tube - He		
Spectral tube – H2		
Spectral tube - N		
Spectral tube – O2		
Spectral tube - Hg		
Fibre optic cable		
S-shaped prism block		
Equilateral prism		
Polarising film slides		
Slinky spring		
Laser pointer - green		
Memory metal		
Bar magnets		
Black crocodile clip**		
Red crocodile clips**		
Black lead 1000mm **		
Red lead 1000mm **		
iPad apps	www.apple.com/uk/itunes	iTunes store
Thoriated rods*	www.weldingsuppliesonline.co.uk	Welding Supplies Online

*items required to make your own cloud chamber **items required to make the 'salad bowl' particle accelerator

If you would like any further information about where the equipment came from, please don't hesitate to contact the project manager.

michaela.livingstone@sciencecentres.org.uk

EXPLORE YOUR UNIVERSE

Age 10 - 13, 1 Hour Workshop

Suggested Script and Activities

Equipment checklist

- **Van de Graaff Generator**
- Pie tins
- Insulating box to stand on
- Strip light
- Wooden ruler

- **Distance to the Sun activity**
- Calculators

- **Infrared camera**
- Bin bag

- **Bar magnets**
- Neodymium magnets
- Iron filings bubbles
- Ferrofluid
- Video camera

In addition to the above equipment you will also need:

- A laptop/computer connected to a projector.
- Access to mains power.

This is a suggested script for a one hour workshop for 10 – 13 year olds. We have given lots of information here for you as presenters, but you may wish to adjust this to suit the needs for your given group. You might also wish to change the order you do the demos, revealing the science after.

Slide 1:

Good morning/afternoon everyone. My name is _________________ and today we are going to look at the work of an organisation called the STFC and the science that they do through the use of some unique equipment.

Slide 2:

Has anyone heard of the STFC?

The acronym stands for the Science and Technology Facilities Council. They work with researchers and industry to keep the UK at the top of international science and engineering*. They are responsible for some of the most ground-breaking research and discoveries being made in the world at the moment.

With so many areas to look at, it would be impossible to look at them all today, so we have picked a selection of the most state of the art projects that are changing what we know about our planet, our universe, and the very stuff we are made of. And with all of this equipment we will see how from atoms to astrophysics, STFC scientists and engineers are changing the world.

*Expansion for higher level groups: Their principal focus is on materials science, space and ground-based astronomy technologies, laser science, microelectronics, particle and nuclear physics, alternative energy production, radio communications and many more areas.

Image Information for slides 2 – 4 (examples of current STFC projects)

Slide 2:

The James Webb Space Telescope (JWST) – an Infrared telescope with a huge 6.5 m mirror diameter due to launch in 2018.

MIRI – the Mid Infrared Instrument designed and constructed by UK scientists is one of the key instruments for the JWST.

Particle accelerator at the Daresbury facility in Cheshire.

Slide 3:

The European Extremely Large Telescope will be the world's largest optical ground based telescope.

The central Laser Facility (CLF) is leading pioneering laser research.

ENVISAT was an Earth observation satellite that unfortunately stopped working in 2012 but delivered a wealth of Earth Observation Data. It is the size of a double decker bus.

Slide 4:

Medical physics – many of the technological breakthroughs STFC projects make have applications in medical physics. This is particularly true for laser technology and the production of radiation, which can be used in medical scanning.

Computer modelling – The STFC's Computational Science and Engineering Department develops world-leading computer simulations for use in a wide variety of research.

STEM (Scanning Transmission Electron Microscope) image of iron particles that have been absorbed into a dendritic (immune) cell.

Slide 5:

To start to understand the world around us, first we need to know what everything is made of. So what is everything made of?

Yes that's right, all matter, all 'stuff', including us, is made from atoms. But what are they made of? We are used to thinking that atoms are as small as it gets, but that is not the case.

Atoms are made up of subatomic particles called protons, neutrons and electrons.

Does anyone know what is at the centre of an atom?

The nucleus contains the protons and neutrons, and the electrons orbit this nucleus a long way away (relatively).

(KS3 students) What is the charge of these sub atomic particles? Protons are positive (+1 charge), neutrons are neutral (0 charge) and electrons are negative (-1 charge). Overall an atom is neutral so the number of protons and electrons must be equal.

So, the subatomic particles that make up atoms are really small. And atoms themselves are full of empty space. But even though they are small, these sub atomic particles can be very useful.

Slide 6:

To begin with, let's think about electrons. Electrons are the smallest of the three main subatomic particles, but what are they responsible for?

They are responsible for chemical reactions and conduction of electricity.

A current is a flow of electrons, so they are very important in understanding how to make electricity.

There is a special type of electricity that we can make using a piece of equipment that we have here, the Van de Graaff generator. We are going to take a closer look at electrons.

Safety warning: Do not allow anybody with a pacemaker, hearing aid or heart condition to take part in this activity. Please refer to the health and safety guidelines on www.exploreyouruniverse.org.

Does anybody know what we mean by an insulator?

Sometimes we use this word to indicate something that does not easily conduct heat, but for this experiment we are thinking about something that does not easily conduct electricity. In the Van de Graaff generator, a pulley rotates driving an insulating rubber belt across a sharply pointed metal comb in the base of the machine. This has been given a positive charge by a power supply.

Does anyone know what charge an electron has?

Electrons are negatively charged. As a result they are attracted to the positively charged metal comb, and are scraped off onto it. This leaves the belt positively charged.

As the positively charged belt moves to the top of the generator it attracts electrons in the metal dome towards it, leaving the dome positively charged (because it has a lack of electrons). We call this build up of charge a voltage. Metals are good conductors of electricity because they have a lot of free electrons that can carry the current.

Charged particles create an electric field and we will talk about fields later, but this electric field can be used to accelerate charged particles because an electric field will interact with a charged particle exerting a force on it.

Activities:

- Making a spark leave the Van de Graaff generator.
- Floating pie tins.
- Hair standing on end (please refer to the Van de Graaff generator briefing sheet for more details).

I mentioned earlier the idea of a field but what is this?

Some of you may have encountered this idea when looking at magnets, but we can also observe the field that the build up of charges (voltage) creates.

The electric field actually extends far beyond Van de Graaff generator and we can see this if we bring a strip light close to it. As the light gets closer it lights up. As we pull it further away it gets less bright until it goes out. This is showing us that the strength of the field is getting less as we get further away.

Simplified explanation: The light contains vapour. When brought close to the Van de Graaff generator the electric field gets strong enough to affect the electrons orbiting the nuclei of the atoms and gives them energy. To lose this energy they produce light that we can see.

Slide 7:

So that is what we mean by a field. Understanding and using fields is very important in science. You may well have come across another common type of field when looking at magnets.

Hand out two magnets to a few students. Magnets have a north pole and a south pole. They generate a magnetic field that runs between the north pole to the south pole.

What happens when you bring a north pole and a south pole of a magnet together?

They are attracted to each other.

What about bringing a north pole to a north pole?

They are repelled. This pushing or pulling force comes from the magnetic fields surrounding a magnet interacting with each other (see ferrofluid briefing sheet for more details).

But how can we see this field?

Just as with the strip light and the plasma ball, we need something that will feel the effect of this magnetic field to show us it.

Get students to work in pairs. Hand out the iron filings bubbles and the bar magnets. Get the students to place the iron filings bubble over the bar magnet and gently tap it.

What can they see?

Iron is a magnetic material and so will be affected by the magnetic field from the bar magnet. This causes the iron filings to be attracted to the magnetic field and line up along the magnetic field lines giving us a visual representation.

Slide 8:

Is the magnetic field only acting in the plane of the paper?

In actual fact the field is three-dimensional, but this is not possible to see in this experiment.

How could we show the three-dimensional field around a magnet?

To do this we are going to use a special material called a ferrofluid. Ferrofluids contain incredibly small particles of materials that are influenced by a magnetic field. These nano-particles are suspended in a fluid. When exposed to a magnetic field, peaks will form within the ferrofluid at points of high magnetic field strength. As a result, the peaks can be used to map magnetic field lines.

(For more details please see ferrofluid briefing sheet).

Place some ferrofluid in a sealed petri dish, or other suitable container, so that it is about 3mm deep. Take a neodymium magnet and carefully move the dish over the top of it observing the 'spiky' appearance created. These spikes are showing where the magnetic field is strongest.

Note: You may wish to use the video camera for this so that everyone can easily see the effects. Please also ensure you use the correct plastic container for the ferrofluid i.e one where the ferrofluid doesn't stick to it.

Slide 9:

How does STFC use fields and their interaction with charged particles?

Ferrofluids: When used with a strong enough magnet, ferrofluids are extremely effective at reducing friction between the magnet being used and a surface. A coating of ferrofluid can actually allow the magnet to glide across a surface with minimal levels of mechanical resistance between the surfaces and could be used to provide almost frictionless joints for machinery and spacecraft.

Ferrofluids are commonly used during MRI (Magnetic Resonance Imaging) and can even be used in detecting cancer.

Magnets are also used in particle accelerators to deflect charged particles. See salad bowl particle accelerator briefing sheet for more details.

Slide 10:

STFC is heavily involved in particle physics research working with several different types of particle accelerator, all of which need a high voltage (like that produced with the Van de Graaff generator) to accelerate particles to very high energies. Particle accelerators accelerate particles to very high speeds, almost the speed of light. Some particle accelerators are used to find out what atoms are made of and to understand how the universe has evolved. Other particle accelerators are used to study the structure of materials and develop new medicines.

There are two main types of particle accelerator: Ones which smash particles together to try to create new particles and ones which store beams of particles to create something called synchrotron radiation. (see particle accelerator briefing sheet for more details).

(Pictures are of the Large Hadron Collider at CERN (left hand) and the Diamond Light Source synchrotron accelerator in Harwell, Oxfordshire (right hand).

Slide 11:

So particle accelerators can be used to study the conditions at the beginning of the Universe, but how can we study what the Universe is like now?

Space is very big. Technically we say it is infinite (goes on forever) and we simply cannot transport people to explore distant stars and galaxies. To help us understand what is going on in the Universe we use telescopes.

Telescopes use mirrors and lenses to collect light and focus it in a way that allows us to magnify distant objects in space.

Some telescopes are based on the Earth such as the European Extremely Large Telescope which the STFC is heavily involved in. But there is a problem with Earth based telescopes.

Can anybody tell me what that problem might be, and why we might want to put telescopes in space?

Our planet has a thick protective atmosphere vital for life to survive on our planet. However this atmosphere scatters light coming from distant objects making it hard to see any detail. To overcome this problem, scientists and engineers have launched many telescopes into space where there is no atmosphere to distort the light.

Slide 12:

The Hubble Space telescope is an example of a hugely successful space telescope project.

Launched in 1990 it has revolutionised our understanding of the Universe and provided some breathtaking imagery. Sadly it is coming to the end of its life now and scientists are working on a replacement.

Slide 13:

The James Webb Space telescope (please refer to IR camera briefing sheet for details).

Slide 14:

Infrared activity

Infrared (IR) is a type of light given off by all objects with a temperature above absolute zero. We also know of it as thermal energy and the hotter an object is, the more infrared light it will give off. While it is not visible to the naked eye, we can use an IR camera to detect and interpret the temperature of objects.

Turn on camera (making sure it is plugged in to the projector and the source is changed to video).

This camera allows us to see who the 'hottest' person in the room is without having to use a thermometer.

Turn camera onto the group and pick out features. Poor circulation will yield dark coloured hands. Some noses may be colder than others. People wearing glasses look like they belong in the matrix – the glasses appear black. Ask the student to remove the glasses and their eyes glow with IR radiation.

What does this tell us the glass is doing to the IR?

It is reflecting and absorbing it so none of it can get through.

How can heat be transferred?

Conduction, convection and radiation.

Get a volunteer to come to the front and remove their shoes and stand on the spot not moving their feet. Look at their feet with the IR camera.

What method of heat transfer will be going on between the feet and the floor?

The thermal energy from the feet will cause particles in the floor to start vibrating as they gain energy, these will get the next particles to vibrate and so on. We call this conduction. You can demonstrate this by getting students to stand in a line and gently move one of them so they bump into the next person who bumps into the next person and so on demonstrating conducting heat.

Get the volunteer to step back and focus the camera on the thermal footprints that have been left behind as a result of thermal conduction.

This concept is important for all spacecraft as we need to be able to conduct heat away from the side of a craft facing the sun to cool that side, towards the colder side to heat that side.

How can scientists use this part of the electromagnetic spectrum to find out more about our Universe?

We can point it out into space. It can be hard to see stars if they are obscured by a cloud of dust and gas. But we are going to select a volunteer to be our star to see how IR can be very useful to space scientists. Here we are going to play the role of the James Webb Space Telescope.

Get a volunteer to step into the bin bag.

Now this bin bag represents a nebula – a collection of dust and gas in space. Using visible light, it is impossible to see our star. But if we use IR, then suddenly they become very clear to us.

Closing statement:

Today we have seen some practical demonstrations of how STFC is allowing the UK to make huge leaps in scientific understanding. There are thousands of STFC scientists and engineers at work right now in the UK, and you could be one of them in the future. From Atoms to Astrophysics, the possibilities for you to explore your Universe are almost endless.

10 - 13 Schools Workshop Curriculum Links

Content Summary (areas common to most or all curricula)

Heat and temperature

- What is heat energy?
- Transfer of thermal energy

Electricity

- Electric charge
- Transfer of electric charge
- Creation of static electricity
- Electric fields and discussion of what we mean by a field

Magnetism

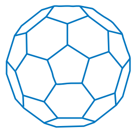
- Bar magnets and observing of magnetic fields
- Interaction of magnetic fields and their uses

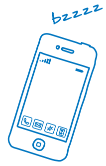
Atoms and elements

- What is matter and what is it made out of?
- Protons, neutrons and electrons
- Basics of atomic structure

Astronomy and our Universe

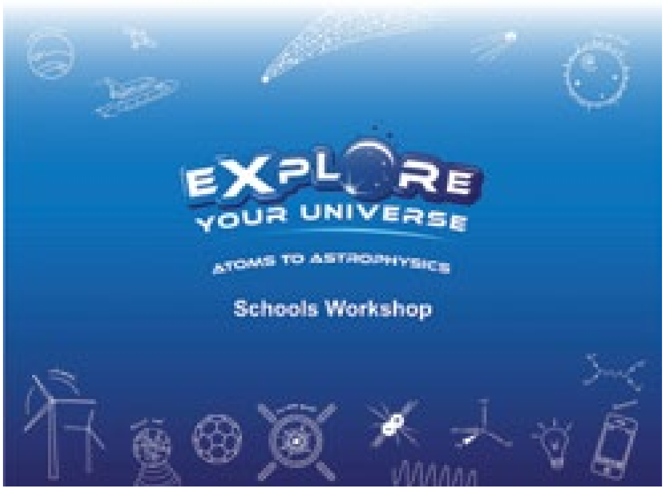
- Earth and space based telescope missions
- Using infrared to explore our universe





Notes

10 - 13 Schools Workshops

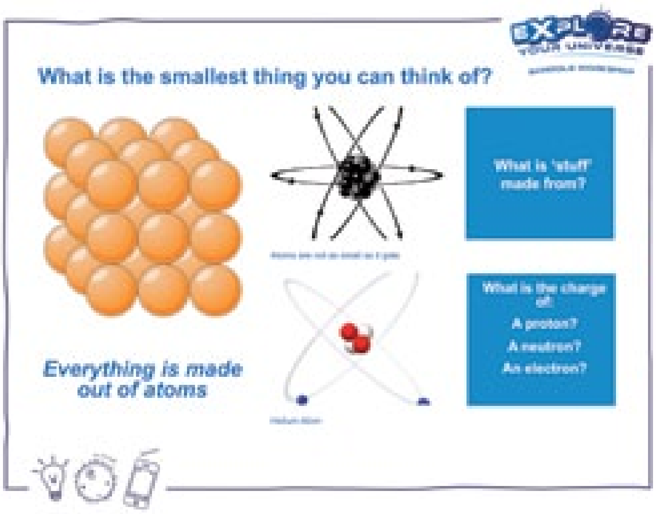


Slide 1 - Notes

Slide 2 - Notes

Slide 3 - Notes

Slide 4 - Notes



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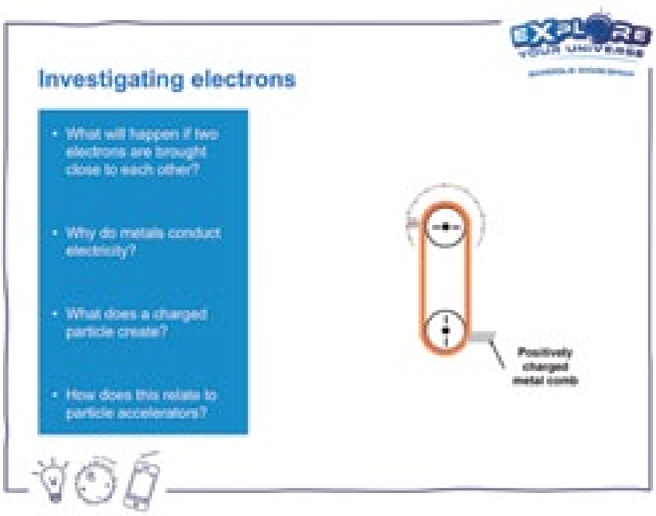

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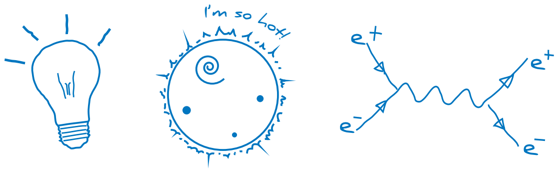
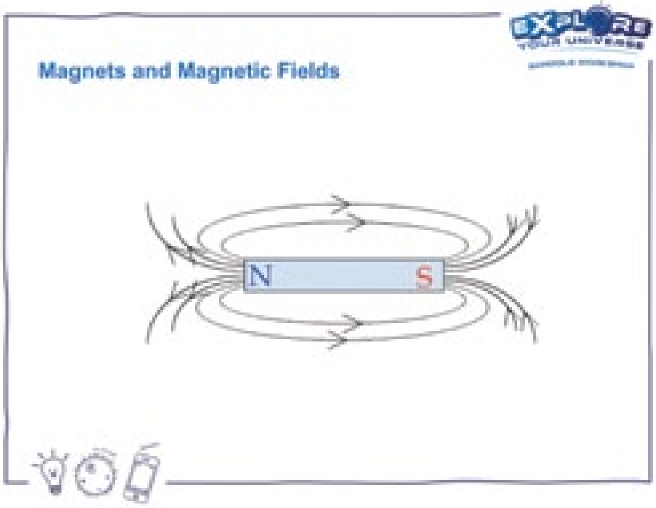
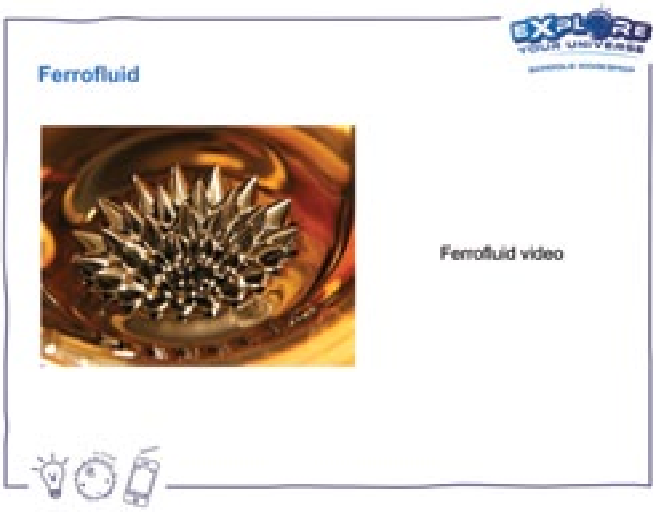


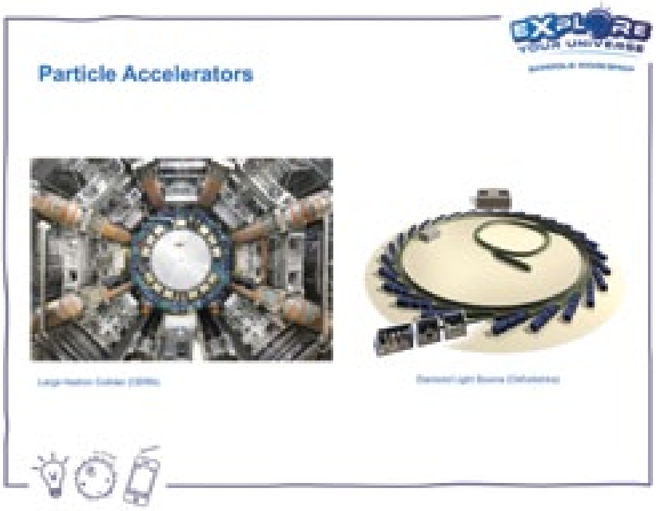


Slide 7 - Notes



Slide 8 - Notes

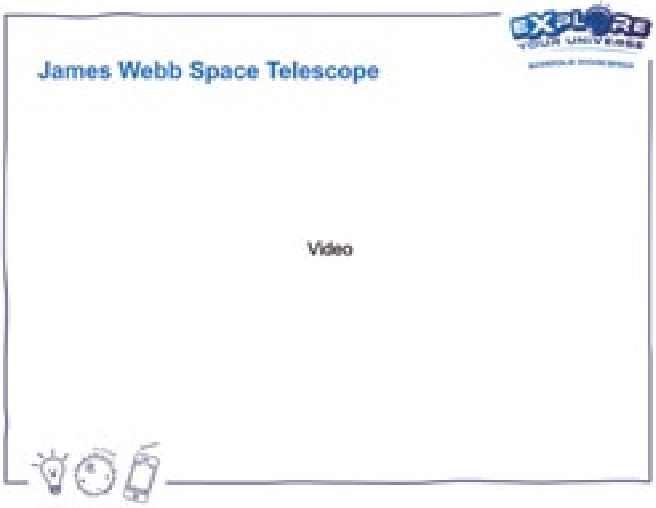
Slide 9 - Notes



Slide 10 - Notes

Slide 11 - Notes

Slide 12 - Notes



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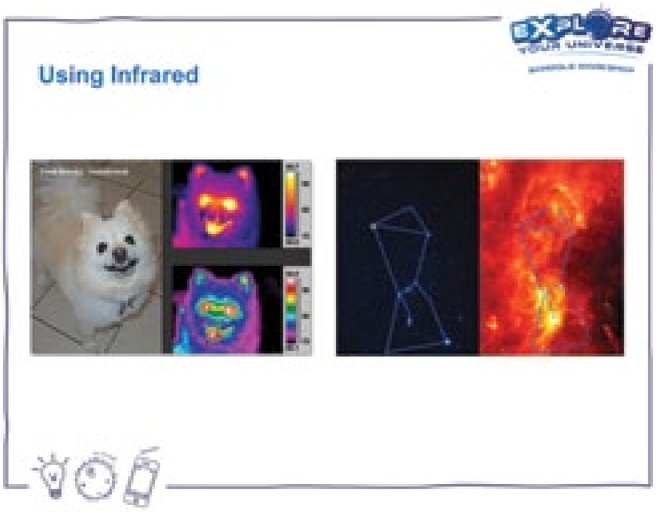

Slide 14 - Notes

Slide 15 - Notes

Notes

Suggested Script and Activities

Equipment checklist

- **Van de Graaff Generator**
- Pie tins
- Insulating box to stand on
- Wooden ruler

- **Particle accelerator bowl**
- Leads
- Crocodile clips
- Metallic table tennis ball
- Insulated object to get ball moving

- **Atom Scale Model Activity Sheet**
- Calculators

- **Cloud chamber**
- Propanol/ethanol
- Dry Ice
- Thoriated rods
- Paper

- **IR camera**
- Tank/plastic box with cold water
- Kettle

- **UV diodes**
- UV pens

- **UV light**
- Sun cream
- Ten pound note/driving license

- **Radiation activity cards**

- **White light source**
- Prism

- **iPad for UV sun link**

Slide 1:

Good morning/afternoon everyone. My name is ______________ _________________ and today we are going to look at the work of an organisation called STFC and the science they do through the use of some intriguing equipment.

Slide 2:

Has anyone heard of the STFC?

The acronym stands for the Science and Technology Facilities Council. They work with researchers and industry to keep the UK at the top of international science and engineering. Their principal focus is on materials science, space and ground-based astronomy technologies, laser science, microelectronics, particle and nuclear physics, alternative energy production, radio communications and many more areas. They are responsible for some of the most ground-breaking research and discoveries being made in the world at the moment.

With so many areas to look at, it would be impossible to explore at them all today, so we have picked a selection of the most state of the art projects that are changing what we know about our planet, our universe, and the very stuff we are made of. And with all of this equipment we will see how from atoms to astrophysics, STFC scientists and engineers are changing the world.

Image Information for slides 2 – 4 (examples of current STFC projects)

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Particle accelerator at the Daresbury facility in Cheshire.

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Slide 4:

Medical physics – many of the technological breakthroughs STFC projects make have applications in medical physics. This is particularly true for laser technology and the production of radiation, which can be used in medical scanning.

Computer modelling – The STFC's Computational Science and Engineering Department develops world-leading computer simulations for use in a wide variety of research.

STEM (Scanning Transmission Electron Microscope) image of iron particles that have been absorbed into a dendritic (immune) cell.

Slide 5:

To start to understand the world around us, first we need to know what everything is made of. So what is everything made of?

Yes that's right, all matter, all 'stuff', including us, is made from atoms. But what are they made of? Atoms consist of subatomic particles called protons and neutrons (in the nucleus) and electrons (orbiting the nucleus at quite a distance).

What is the charge of these sub atomic particles?

Protons are positive (+1 charge), neutrons are neutral (0 charge) and electrons are negative (-1 charge). Overall an atom is neutral so the number of protons and electrons must be equal.

Slide 6:

Activity: Size of the atom. Please refer to the activity guide on **www.exploreyouruniverse.org**

So, the subatomic particles that make up atoms are really small. And atoms themselves are full of empty space. But while small, these sub atomic particles can be very useful.

Slide 7:

To begin with let's think about electrons. Electrons are the smallest of the three main subatomic particles, but what are they responsible for?

They are responsible for chemical reactions and conduction of electricity.

We are going to take a closer look at electrons using a piece of equipment called a Van de Graaff generator (please refer to briefing sheet for explanation of how it works and experiments to try).

Slide 8:

Can electrons be split into anything smaller? No. What about protons and neutrons?

To find this out, scientists have constructed particle accelerators to smash protons into protons at high speed, breaking them down to their smallest constituent parts. We can get an idea of how a particle accelerator works by again using the Van de Graaff generator (see particle accelerator briefing sheet).

In this example we are using a change in charge to accelerate the particle. In real particle accelerators protons are accelerated by a changing electric field.

Slide 9:

Scanning Transmission Electron Microscopy (STEM) – please see Van de Graaff briefing sheet for more details

Slide 10:

But how fast do they go? What is the fastest thing you know of?

Light travels at 300,000,000 m/s. The protons in the LHC are travelling at almost this speed.

But why does smashing protons into protons matter? Well, we know that there is more to an atom than protons, neutrons and electrons. In fact for over a hundred years scientists have been observing effects that begged the question, "what else is there?", or rather, "just how small can we go?"

Slide 11:

Ever since radiation has been observed, scientists have known that there had to be something other than just protons, neutrons and electrons. And we actually have a piece of equipment that will allow us to see some of these 'things'.

But first, let's see what we know about radiation.

Activity – radiation recap. Please refer to the activity guide on www.exploreyouruniverse.org

How can we observe this radiation? We are going to use a piece of equipment called a cloud chamber (for details on this demonstration please refer to the cloud chamber briefing sheet).

Slide 12:

So now we will move on from looking at very small things, to something much bigger, and far more noticeable to us. (Point to thermal image of the Earth) Can anyone tell me what this is?

Yes it is our planet but what do the colours show? They are showing the temperature of the oceans. Right now there is a small army of Earth Observation Satellites looking down at our planet, feeding scientists information about what is changing, and any problems that may arise.

How can we know about the temperature from space – we certainly don't have a big enough thermometer.

Well the STFC is involved in many of these Earth Observation Projects, and they all have a common theme. While they may not all use visible light to gain their information, they do still use light, just different types.

Slide 13:

Demonstrate splitting white light into a rainbow using a prism from the optics box (please refer to briefing sheet for guidance). What happens to white light when you shine it through a prism? It splits into its constituent colours forming a rainbow. Just like there are different colours of visible light, each corresponding to a different wavelength

(for higher ability groups, bring in:

wave velocity (in metres per second) = frequency (in Hertz) x wavelength (in metres)

with red having a longer wavelength and lower frequency than blue).

As the light passes from the air into the prism at an angle to the normal (a line perpendicular to the surface of the prism) it is refracted (bent), and different wavelengths of light will be refracted by different amounts. This allows us to split the white light in to its constituent colours.

Slide 14:

There are also many other types of light that, whilst we cannot see, are very useful to us. They each have their own range of wavelengths and frequencies.

What do we call this spectrum of 'light'?

We call it the electromagnetic spectrum. Look at the image of the electromagnetic spectrum. It is a family of waves, with visible light right in the middle.

What happens to the wavelength of the light as you move towards the infrared?

It gets longer.

What happens to the wavelength of the light as you move towards the ultraviolet?

It gets shorter .

Which of these two is also known as heat radiation?

Infrared radiation is also known as heat radiation.

Anything that is above absolute zero, the lowest temperature that it is possible to get to, gives off infrared (IR) radiation. The hotter an object is, the more IR it will emit due to atomic/molecular vibrations and associated temperature. We can use this to remotely find out information about the temperature of objects.

IR activity:

Turn on camera (making sure it is plugged in to projector and the source is changed to video).

This camera allows me to act like an Earth observation satellite. In fact, it allows me to see who the 'hottest' person in the room is without having to use a thermometer.

Turn camera onto the group and pick out features. Poor circulation will yield dark coloured hands. Some noses may be colder than others. People wearing glasses look like they belong in the matrix – the glasses appear black. Ask the student to remove the glasses and their eyes glow with IR radiation.

What does this tell us the glass is doing to the IR?

It is reflecting and absorbing it so none of it can get through.

How can heat be transferred?

Conduction, convection and radiation.

Get a volunteer to come to the front and remove their shoes and stand on the spot not moving their feet. Look at the feet with the IR camera.

What method of heat transfer will be going on between the feet and the floor?

The thermal energy from the feet will cause particles in the floor to start vibrating as they gain energy, these will get the next articles to vibrate and so on. We call this conduction.

Get the volunteer to step back and focus the camera on the thermal footprints that have been left behind as a result of thermal conduction.

This concept is important for all spacecraft as we need to be able to conduct heat away from the side of a craft facing the sun to cool that side, towards the colder side to heat that side.

We can even simulate observing the oceans by pouring hot water into cold and observing the thermal currents created.

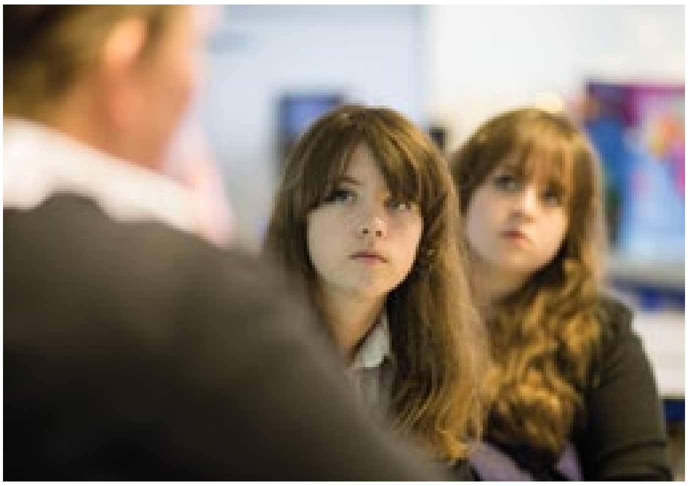
How can scientists use this part of the EM spectrum to find out even more about our Universe?

We can point it out into space. It can be hard to see stars if they are obscured by a cloud of dust and gas. But we are going to select a volunteer to be our star to see how IR can be very useful to space scientists.

Get a volunteer to step in the bin bag.

Now this bin bag represents a nebula – a collection of dust and gas in space. In the visible spectrum, it is impossible to see our star. But if we use IR, then suddenly they become very clear to us. Projects such as Herschel are scanning the sky to find as many IR sources as possible to widen our knowledge of the Universe.

For more ideas on IR activities, please see IR camera briefing sheet.



Slide 15:

Higher ability extension: Red Shift.

Infrared is useful for another reason. As scientists looked out at the universe an interesting fact became clear. The light from these stars was redder than they would have expected, and the light from the furthest objects was even redder still. In fact Hubble discovered that there was a direct link between how far away an object was and how 'red' it was. Why is this?

Elastic band demo for red shift. Get students to draw a wave onto an elastic band. Now get them to hold one end in a fixed position. Students then use the other hand to stretch the elastic band away from them, representing a receding (moving away from them) galaxy. What happens to the wavelength of the light? It gets longer, so is shifted towards the red part of the spectrum. What about if they come towards you? It gets shorter and so is blue shifted. If almost all of the light is getting red shifted, what is this telling us about everything in the Universe? It is travelling away from us.

Get students to mark points on a balloon which represents the universe. Get them to blow up the balloon and watch what happens to all of the points. Each point is moving away from every other point, just like we have observed. The balloon is expanding, and so is our Universe. This was one of the key pieces of evidence for the big bang.

Slide 16:

James Webb space telescope case study – could the oldest things in the universe be so red shifted that they have been shifted into the IR part of the spectrum? Please refer to IR camera briefing sheet.

Slide 17:

What do we know that gives off lots of light AND heat?

The Sun, our nearest star is a burning ball of gas that is emitting EM radiation constantly. And as well as IR, there is another part of the EM spectrum that we can use. And this is ultraviolet (UV).

Ultraviolet activity – please see UV Pens and Diodes briefing sheet.

What do we know about UV?

It has a shorter wavelength, higher frequency and therefor a higher energy than visible light.

Higher ability extension - the formula E (energy of a photon of light) = h (Planck's constant) x f (frequency of the light in Hertz) to work out the energy of a particular type of light. The higher the frequency, the higher the energy the light will have.

As such it is what we call an ionising radiation – it has the power to give electrons orbiting a nucleus a large amount of energy. In some cases it gives them enough energy to escape the atom leaving it ionised.

What can UV light do to us?

In high enough exposures it can cause sunburn. It can damage your retina in your eye. And in extreme cases, it can lead to DNA mutating and dividing in an uncontrolled manner leading to skin cancer.

Gather students around the UV light.

A common use of UV is in security. Driving licences and money re all marked with UV fluorescent ink. This means that when the UV hits the ink, electrons in the atoms of the ink gain energy and become excited. To lose this excess energy they give off a little packet of visible light called a photon. These photons are what we can see when we look at a £10 note under the UV lamp.

We mentioned before that UV can cause sun burn or even skin cancer. If you are going to be out in the sun all day what should you use to protect yourself from this?

Sun cream stops the UV from getting to your skin, but we can test whether it works right here.

Place a piece of white paper under the UV lamp and watch as it gives off light (fluoresces). Now pull the paper away, coat your hand in sun cream and make a hand print on the paper. Place the paper under the lamp again and you will see a dark hand print where the UV is unable to get through to the paper and so no electrons can be excited, and no photons of light released.

So how is UV used by the STFC?

Our Sun emits a particularly large amount of UV light. By observing the Sun in this part of the EM spectrum we can find out a lot about the high energy processes going on, including solar flares (massive outpourings of energy that bring a stream of charged particles).

On the slide you can see two solar observation missions that the STFC is involved in. SOHO, or the Solar and Heliospheric Observatory, primarily observes the Sun in UV. SDO, or the Solar Dynamics Observatory, also focuses extensively on the UV part of the EM spectrum and is specifically investigating magnetic activity in the Sun and how it affects solar flares.

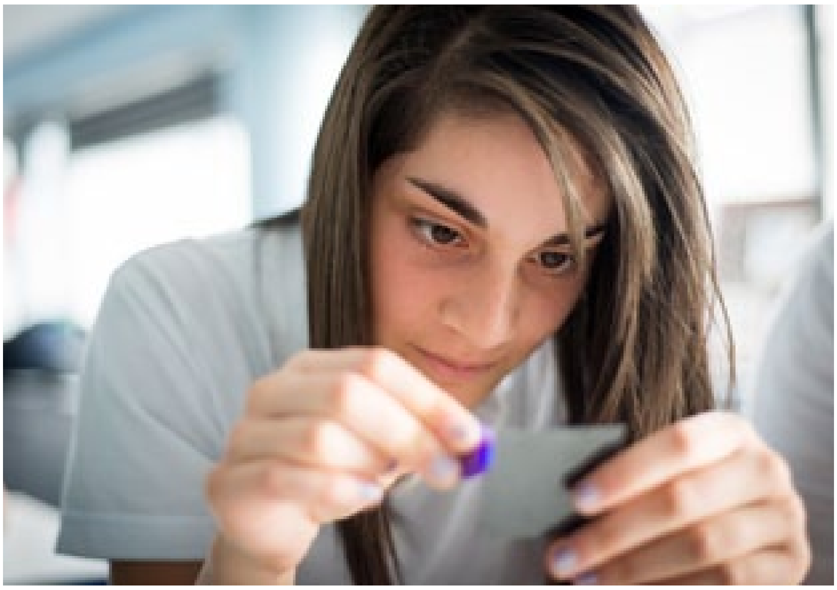
STEREO is an ambitious mission using two solar observatories to monitor the Sun and the region between the Sun and the Earth. The two identical probes are offset from one another, one flying ahead of the earth in its orbit and the other behind the earth. The spacecraft look back at the sun and the space between the sun and the earth. This allows 3D images of the sun to be produced.

Slide 18:

It is the STFC RAL Space-led Heliospheric Imagers (HI) on STEREO that looks at the space between the sun and the earth, using wide-angle telescopes. They are being used to detect the Coronal Mass Ejections (CMEs – a storm of high energy charged particles that follows a solar flare) as they push through space, occasionally towards the Earth.

Closing statement:

Today we have seen some practical demonstrations of how STFC is allowing the UK to make huge leaps in scientific understanding. There are thousands of STFC scientists and engineers at work right now in the UK, and you could be one of them in the future. From Atoms to Astrophysics, the possibilities for you to explore your Universe are almost endless.



Content Summary (areas common to most or all curricula)

Energy and the EM spectrum

- Constituents of the EM spectrum and the relationship between wavelength and frequency
- Infrared radiation as thermal energy
- The link between kinetic energy and thermal energy in a material
- UV light as higher energy ionising radiation and the effects on organisms and different materials
- Excitation of electrons and emission of photons
- Transfer of thermal energy – conduction, convection and radiation
- Red shift and what it tells us about the Universe

Electricity and fields

- Free electrons and the generation of current
- Static electricity – how it is generated and its effects
- Electric fields and their uses in particle physics
- Interactions of charged particles
- Insulators and conductors – their properties and uses

Atoms and radiation

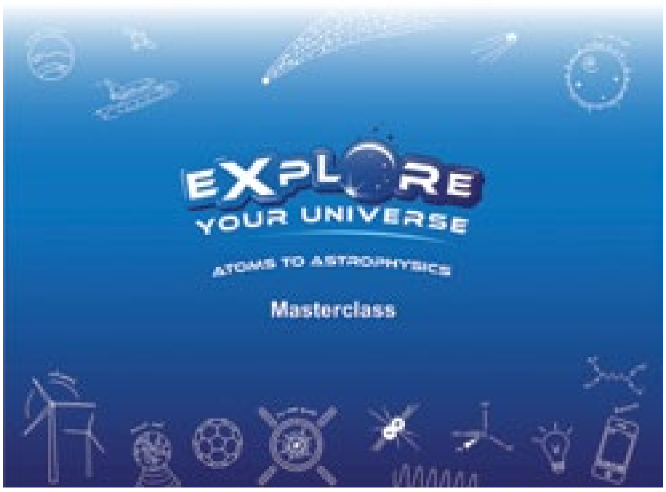
- Structure and size of an atom
- Subatomic particles and their properties
- Radiation – alpha, beta and gamma radiation, radiation properties and how to observe radiation through the use of a cloud chamber

Demonstrations and activities

- Calculations of scale distance and modeling of an atom
- Van de Graaff generator – generating static electricity and the interaction of charged particles
- Salad bowl particle accelerator – interaction of charged particles and electric fields as an analogue for current particle accelerators
- Infrared camera – analyzing temperature, thermal transfer, uses in astronomy and Earth observation. Analogues for space telescopes
- UV light and UV pens – puzzle investigation to uncover information about UV light. How electrons orbit in discrete energy levels and excitation and relaxation lead to the emission of photons. Use of UV for solar observation

Notes

14 - 16 Master Class

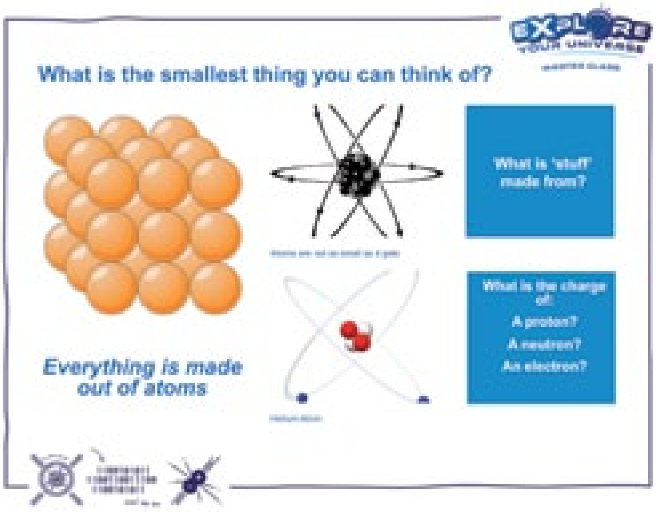


Slide 1 - Notes

Slide 2 - Notes

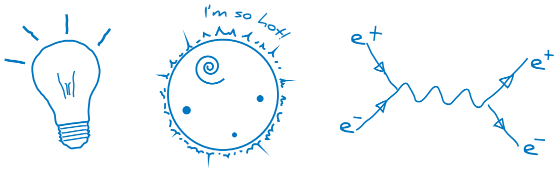
Slide 3 - Notes

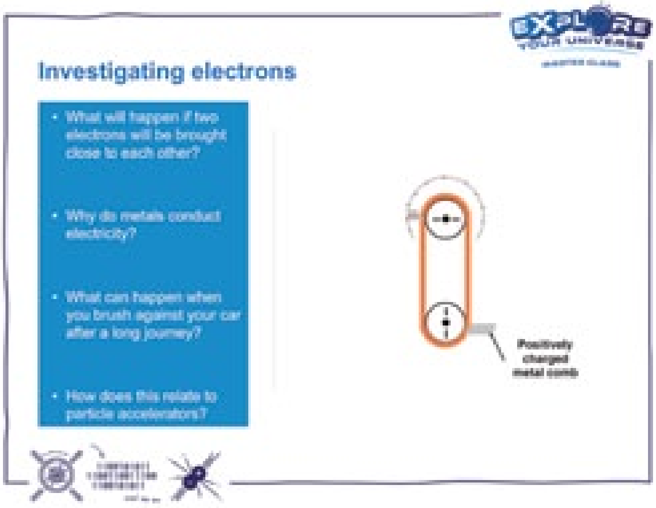
Slide 4 - Notes



Slide 5 - Notes

Slide 6 - Notes



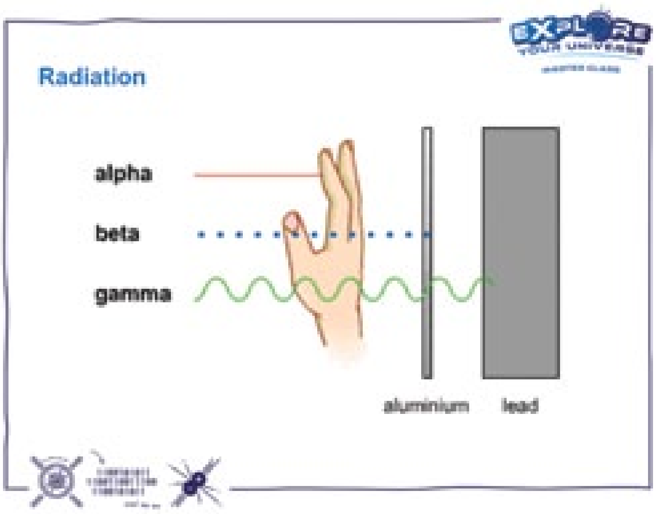


Slide 7 - Notes

Slide 8 - Notes

Slide 9 - Notes

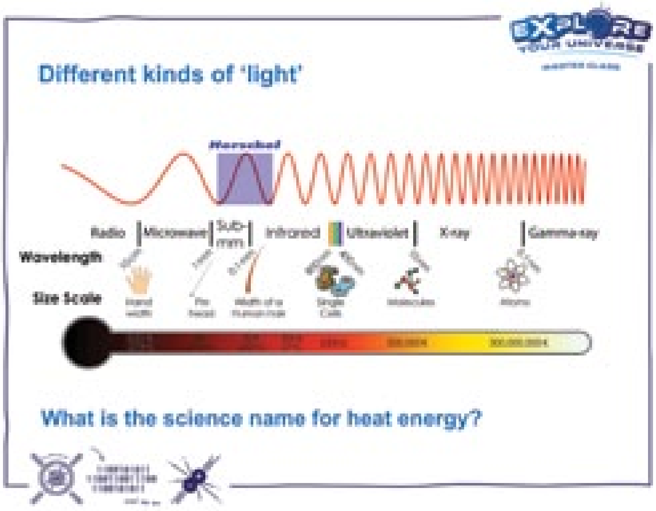
Slide 10 - Notes



Slide 11 - Notes

Slide 12 - Notes

Slide 13 - Notes



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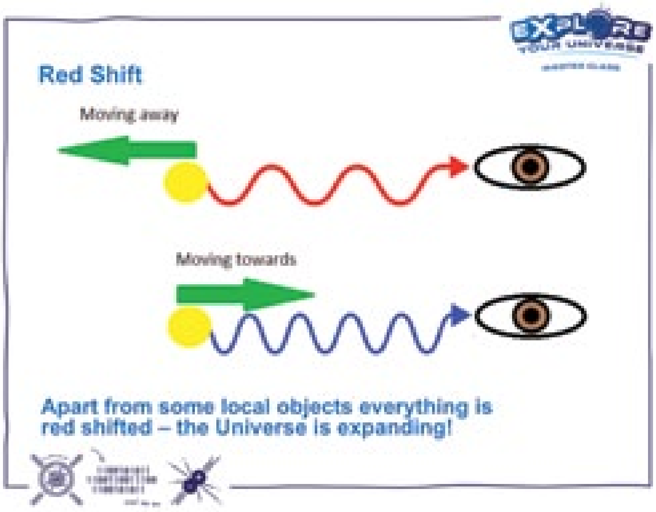


Slide 15 - Notes

Slide 16 - Notes

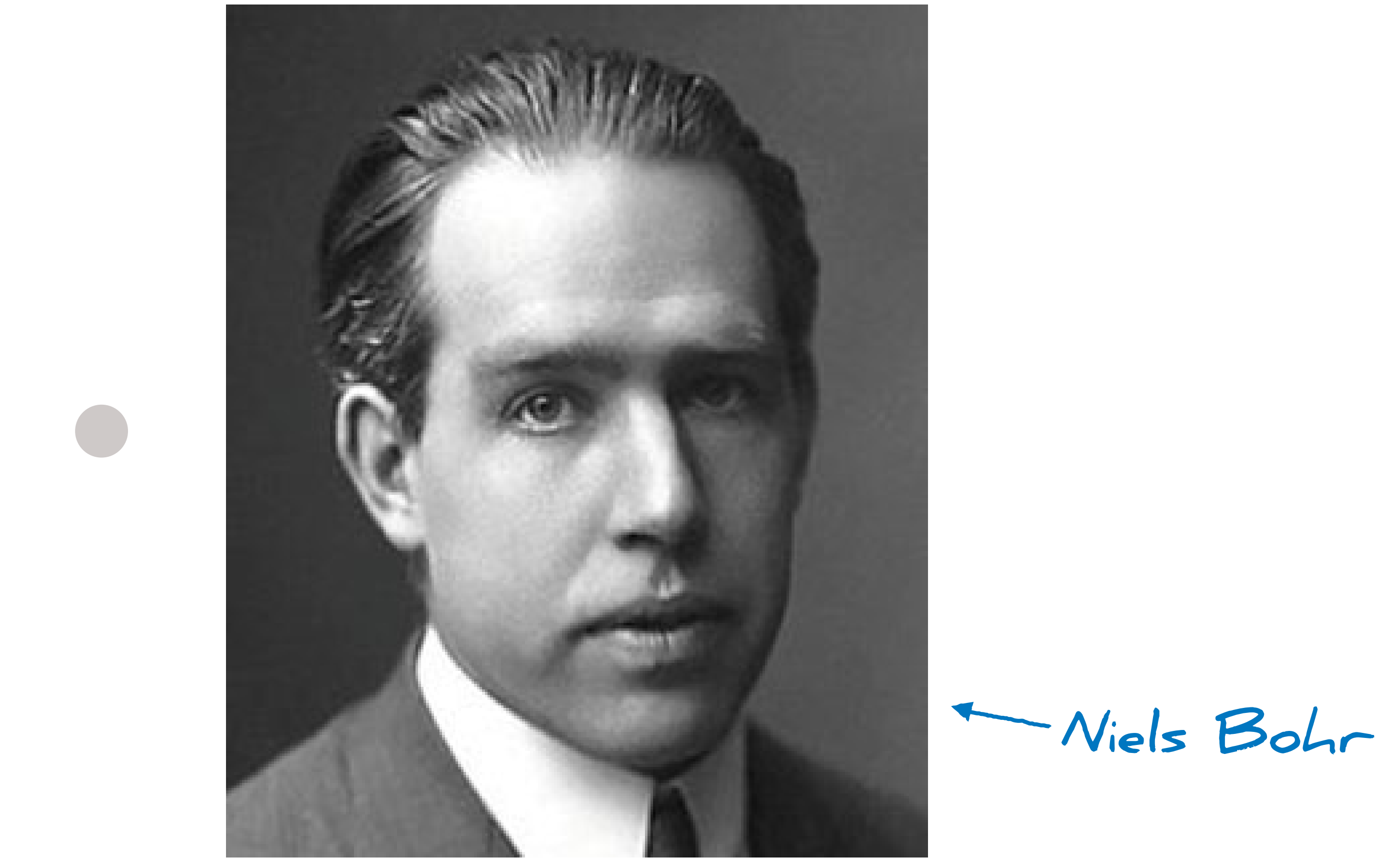
Slide 17 - Notes

Slide 18 - Notes

Slide 19 - Notes

Notes

Notes



Scale model of a Hydrogen atom

Question

When describing the size of an atom, the numbers involved are incredibly small.

A Hydrogen nucleus for example has a diameter of about **1×10^{-15} m (or 0.000000000000001m).**

The most probable distance that an electron will orbit the nucleus in a Hydrogen atom is called the Bohr radius (after Niels Bohr, the scientist who developed the model of the atom with the nucleus at the centre and electrons in orbit around it) and is given as **5×10^{-11}m (0.00000000005m).**

What would the diameter of the atom be?

If you wanted to make a scale model of the Hydrogen atom and decided that the nucleus would have a diameter of 1 mm, what would be the diameter of the entire model?

Note: This is a simplistic model that gives us an idea of how much empty space there is in an atom.

Scale model of a Hydrogen atom
Answer

When describing the size of an atom, the numbers involved are incredibly small.

A Hydrogen nucleus for example has a diameter of about
1×10^{-15} m (or 0.000000000000001m).

The most probable distance that an electron will orbit the nucleus in a Hydrogen atom is called the Bohr radius (after Niels Bohr, the scientist who developed the model of the atom with the nucleus at the centre and electrons in orbit around it) and is given as **5×10^{-11}m (0.00000000005m).**

What would the diameter of the atom be?

Answer $5 \times 10^{-11}\text{m} \times 2 = 1 \times 10^{-10}\text{m}$

If you wanted to make a scale model of the Hydrogen atom and decided that the nucleus would have a diameter of 1 mm, what would be the diameter of the entire model?

Answer The easiest way to do this is to set up a ratio:

Diameter of nucleus/diameter of atom = 1mm/diameter of scale model

1mm = 0.001m

So: 1×10^{-15} m/1×10^{-10}m = 0.001m/diameter of scale model

So: 1×10^{-5} m = 0.001m/diameter of scale model

Rearranging gives us: diameter of scale model = 0.001/1×10^{-5} m

Diameter of scale model = 100m

Note: This is a simplistic model that gives us an idea of how much empty space there is in an atom.

Radiation Activity

alpha	α	Two protons and two neutrons bound together - effectively a helium nucleus	Can be blocked by a sheet of paper
beta	β	High energy, high speed electrons emitted from an atomic nucleus	Blocked by a few centimetres of metal
gamma	γ	High energy electromagnetic wave emitted during energy changes within a nucleus	Can pass through large widths of concrete and requires thick lead to block it

Laminate this page and cut the above into cards. Hand these cards out to students (one set between two) and get them to try and match up the right qualities to the radiation types.

Family Science Show

Introduction

This 30 minute show is aimed at an audience of families with children between the ages of 8 and 13. The content and show length may therefore not be suitable for very young children.

The show should be presented by a single presenter and will probably work best with audiences of 50 people or more. This does not mean it cannot be presented to smaller audiences but certain elements of the show may not work so well.

There is no set PowerPoint to accompany this show, although you might wish to use some of the pictures from the workshop PowerPoints to illustrate elements of the show.

Since the age range of the audience for this show is so varied, some bits will be more suited to the children and some to the adults. It is not necessary that the 8 year olds in the audience understand everything; this is a show for families, not a show for 8 year olds. If an 8 year old sees something and is amazed and intrigued and goes away with an increased interest that is absolutely fine.

The content is flexible for you to mix and match. For example, you might want to add the Van de Graaff demonstration of hair standing on end, or any of the plasma ball experiments.

Kit required

You will need the following pieces of kit from the Explore your Universe kit:

- Salad bowl particle accelerator including ball, leads and crocodile clips
- Van de Graaff generator including container with foil balls in it
- Small liquid Nitrogen dewar + safety equipment
- Levitating magnets using superconductors kit
- White light source including slits and lenses
- Laser pen
- Prism
- Diffraction grating
- 2 materials from the materials box
- Infrared camera
- Video camera

You will need to supply yourself:

- Access to power sockets
- Paper or Styrofoam cup (this is to pour a small amount of liquid nitrogen into. This can then be poured onto the superconducting magnet kit more accurately than tipping straight from the flask)
- Liquid Nitrogen
- Scale model of solar system

The show

Atoms

After introducing the show and yourself, start by talking about atoms:

What is an atom?

The basic building block that everything is made of – there are many different types!

How big is an atom?

Answer is around 100 trillionths of a metre, that is 0.1 billionths or 10^{-10}m if you understand this form of notation

Is an atom made up of particles?

Yes, protons and neutrons in the nucleus and electrons orbiting the nucleus

So how big is the nucleus?

Around 10,000 times smaller than the atom – if the atom were the size of a football stadium, the nucleus would be a marble in the middle!

So we are mainly made of empty space!

Particle accelerators

Particle accelerators accelerate particles to very high speeds, almost the speed of light. Some particle accelerators are used to find out what atoms are made of and to understand how the universe has evolved. Other particle accelerators are used to study the structure of materials and develop new medicines.

Show the **salad bowl particle accelerator** powered by the **Van de Graaff generator**. You may need to use the camera so that everyone can see what is happening inside the bowl.

Particle accelerators need a high voltage to make the particles go fast. Here the voltage is being supplied by the **Van de Graaff generator.** Show what effect the voltage (which in this case is a build up of static charge) can have by putting the container with balls of foil, which is supplied, on top of the dome.

Safety note: Be sure to follow the health and safety instructions on the Van de Graaff generator briefing sheet.

Next show the **salad bowl particle accelerator** in action, explaining that the **Van de Graaff generator** is supplying charge to the metal strips which in turn is accelerating the metal coated ball (a full explanation of how the salad bowl particle accelerator works can be found on the briefing sheet for this piece of equipment).

Particle accelerators use magnetic fields to steer the particles (rather than the side of a salad bowl which is what is happening here). These magnetic fields have to be very strong to give a big enough force to steer the particles enough. To get a strong magnetic field you have to cool down your magnet until it becomes superconducting – that means electricity can pass through it with no resistance. Other strange effects happen when particles become superconducting. Demonstrate Strong Levitation (instructions are in the kit) with the **Levitating magnets using superconductors kit**. You will need **liquid Nitrogen** for this demonstration. You will also need to use a camera to ensure all your audience can see what happens.

There are two main types of particle accelerator: Ones which smash particles together to try to create new particles and ones which store beams of particles to create something called synchrotron radiation. Synchrotron radiation is a type of light. We also know other types of light. Normal lights, e.g. a torch and lasers. So what is synchrotron radiation?

Light and Synchrotron Radiation

Shine the **white light source** on a wall across the stage to show that the spot size is quite large. Shine a **laser pen** across the stage in the same way to show a small spot size. Synchrotron radiation is like the laser; it is highly collimated and has a very small spot size. This means that it can be used to carry out far more accurate experiments than white light.

Now shine the **white light source** through a **prism** to show a rainbow. Shine the **laser pen** through the **prism** and show that you don't get a rainbow (be careful that the laser beam doesn't get bent and end up going in someone's eyes). Synchrotron radiation is like the white light source; it is made up of many colours including things outside of the visible spectrum, such as infrared, ultra-violet and X-rays.

So how do researchers use synchrotron radiation? In broad terms, they shine it through materials and look at the patterns the light makes. These patterns tell them about the structure of the material.

Take the **diffraction grating** and shine the **laser pen** through one set of slits so that the resulting pattern shows up on a wall (again, take care that the laser beam doesn't hit anyone). Compare this pattern with the other sets of slits. You should see that spacing of the laser beams varies with the spacing of the slits in the diffraction grating. Scientists look at the spacing of the beam after it has passed through a material and use this spacing to work out the spacing of the atoms or molecules in a material (the material acts like a diffraction grating because the atoms and molecules have a regular spacing).

Safety Note: Always be carefully to ensure that the laser light is not going in to anyone's eyes.

Our world and materials

When lots of atoms are put together we get materials which we can see and use. Depending on which atoms we use and how we put them together will get different materials with different properties.

Choose two examples from the **materials box** and demonstrate or talk about them.

Possible examples:

Show the **aerogel** and talk about its properties

Show how **memory metal** works

Show how **ferrofluid** acts around magnets

Talk about **meteorites** and pass the sample around for people to look at

Beyond our world

Moving on to things which are even bigger than everyday objects, we have Space. The Earth orbits the Sun in our Solar System, our Solar System is one tiny part of our Galaxy, and our Galaxy is just one of billions in the universe. All of these objects are still made of atoms which we started talking about at the start of the show.

So just how big is our Solar System?

Use your **scale model of the Solar System** (or just a scale model of Earth and Moon) to show this. A simple scale model of the Earth and Moon can be made with a football (approx 18cm diameter) and a tennis ball (approx 5cm diameter). Hold onto the Earth and ask the audience how far away the Moon should be on this scale. The answer is 5.5m away. For comparison it is ~1km to Mars and ~2km to the Sun on this scale.

We can see the Sun and most of the planets in our solar system in our sky. But how do we see objects which are further away?

The answer is that we use telescopes.

Astronomers look in space to find out about our Universe. They look through telescopes to do this. They don't only use telescopes with visible light though; they use telescopes over the whole electromagnetic spectrum (see various briefing sheets for the optics box for help on this). The rainbow extends beyond the colours you can see to infrared, microwaves and radio waves in one direction and to ultra violet, X-rays and Gamma rays in the other direction.

Show the audience the **Infrared camera**. Ideally you need to hook the camera up to a projector so that everyone can see what is happening. Have a look around the room with camera and talk about what you can see. Explain that the camera is picking up infrared radiation (which we know more commonly as heat). Examples of things to demonstrate are on the Infrared camera briefing sheet.

We have now explored STFC science all the way from atoms to astrophysics. That is the end of the show.

Notes

Meet the Expert Session: Format

MEET THE EXPERT

What is it?

A Meet the Expert session is mainly an opportunity for members of the public (or a more specific audience) to formally, or informally, talk to someone who works in the fields of science and engineering about the subject area in which they work. Most centres will already run similar sessions, these are suggested formats that has worked well for others, and we have included some things to consider that may help the session run more smoothly.

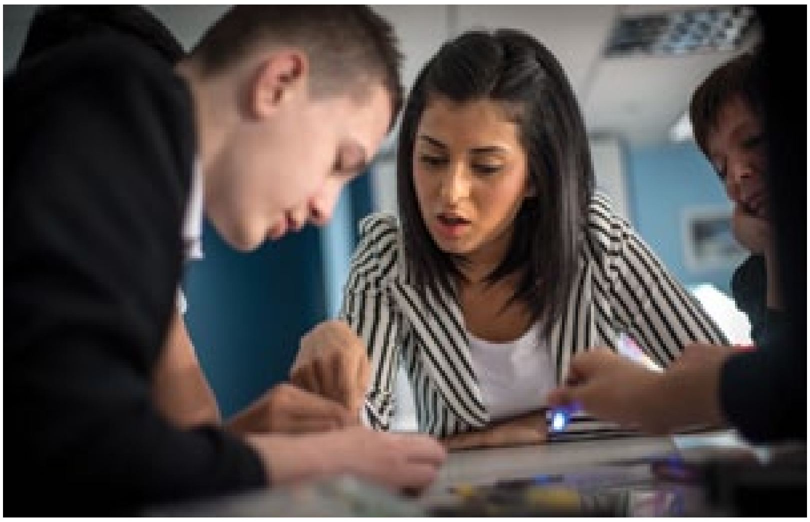
This sheet assumes you have already found an Expert and agreed a time and place for the session to take place. Advice on how to go about this will have been given in the training academy.

Different Types of Experts – and Sessions:

There are different types of science and engineering experts who could come to your centre for your session. Some may be busy senior researchers, who can only spare an hour or so. Others may be postgraduate researchers, who may be able to spend longer at the centre. The first thing you should therefore consider is the length of time for which they will be at your Centre.

An Expert who is with you for only a short length of time can deliver a 'Short Meet the Expert Session' (e.g. over lunch time or as an introduction to an evening event). The description of how to deliver this is given below under 'Short Meet the Expert Session'.

An Expert who can be present in your centre for longer (e.g. half / whole day) – can be given a stand somewhere in your exhibition space that they can use as a base. This can be a place where they put up display materials (such as pop-up banners etc); use some of the project equipment to demonstrate their science; and speak to passing members of the public. The description of how to set this up is given under the heading 'Meet the Expert stand'. Note that experts who are in your centre for longer are often happy to discuss their work with people in both ways, so may also be willing to deliver one or more Short Meet the Expert Sessions while they are with you.



Short Meet the Expert Session:

This type of session could take place in your show space, café, or a room used for talks or presentations. The audience will be seated facing the Expert and the Expert may need a lectern, AV equipment, a projector and a table for their demonstration equipment etc. The Expert should arrive well in advance of the session so there is sufficient set-up time and a staff member should assist the Expert in getting ready for the session.

Once the audience is gathered, a staff member should introduce the Expert and remain in the room for the duration of the session. As an introduction, the Expert should tell the audience about what they do in sufficiently simple terms that a member of the public with no particular scientific training can understand, in a section which lasts around 10 minutes. Prior to their visit, the Expert should be advised on the sorts of presentation that would suit the needs of the expected audience, for example by avoiding using text - using interesting images instead. The Expert should also be asked to describe any pictures that they use.

Ideally the Expert should also include a short hands-on demonstration using some of the Explore your Universe Kit or by bringing their own kit. If the expert brings their own kit please remember that you are responsible for doing a risk assessment of the activity; this also applies if the expert uses the Explore your Universe kit in a way which has not already been risk assessed by the project team. The demonstration should be related to the broad field which they study (e.g. Astronomy) but it may or may not be directly related to their precise field of research (e.g. supernovae).

Once this introductory session is over the remainder of the session can be used for the Expert to engage the audience in dialogue about their fields of research or work, by taking questions and discussing their ideas. The staff member can stimulate discussion by posing questions to both the audience and the expert. Up to 30 minutes is a good duration for this section

While the Expert may be wearing a microphone to help the audience hear them it is important to remember audience members are not. Therefore each question should be repeated by the Expert after the audience member asks it so that all other members of the audience can hear the question (this will help avoid the same question being asked twice).

The member of staff can facilitate the session, e.g. by trying to take questions from as wide a range of people as possible; try not to let any one person ask more than two or three questions and make sure everyone who wants to, gets to ask at least one. If it appears a member of the audience is dominating proceedings, tell them diplomatically that someone else should be given a chance to ask a question. The Expert can offer to speak to people on an individual basis after the formal session has ended if they feel comfortable with this.

Since this format is aimed at families it is likely there will be small children in the audience. If a small child becomes disruptive you can first explain to the child that they need to sit quietly and that if they want to ask a question they should put their hand up (school age children will already be familiar with this system). If they continue to be disruptive you can ask their parent or adult who is responsible for them to step in. These actions may become necessary if they are preventing the session from continuing.

It is likely that questions will be asked which are outside of the field of expertise of the Expert. It is up to the Expert how they handle these. If they feel they can contribute something to an answer then they should but making sure they only say things which they know to be true. Alternatively they can choose to not answer the question, and simply say that they do not know the answer to that one.

A few minutes before the end of the session the staff member should warn both the Expert and the audience that time is almost up and that there is only time for a couple more questions. Once these questions have been taken and answered the staff member should thank the Expert and can try to summarise the discussion, such as repeating any very intriguing answers or questions that have come up.

Ask an Expert Stand:

The Expert should be invited to arrive at a pre-arranged time (prior to the time advertised to the public) and should be greeted by a member of staff. Ideally, this member of staff should be responsible for the Expert (including any equipment they may need, the safety of their belongings and their well-being) while they are at your centre. The staff member must make sure that the Expert is aware of the location of all relevant facilities and also any health and safety requirements such as fire alarms, exits and muster points.

The Expert should be given a stand area at a suitable position within the centre. Ideally this will bring lots of people past them during the day, but it should not be a place that will block access for other visitors or fire exits etc. The staff member should assist the Expert in setting up any equipment or display material that they would like to use.

The Expert should ideally include some hands-on demonstration in their stand using some of the Explore your Universe Kit or by bringing their own kit, which you should check complies with your centre's Health and Safety and PAT testing (etc) requirements. Please remember that you are also responsible for doing a risk assessment of any activity for which the Expert brings their own kit; this also applies if the expert uses the Explore your Universe kit in a way which has not already been risk assessed by the project team. The demonstration they set up should be related to the broad field which they study (e.g. Astronomy) but it may or may not be directly related to their precise field of research (e.g. supernovae). This format allows maximal informal discussions to take place between the expert and the audience. A member of staff can help by encouraging the audience to ask lots of questions.

The staff member should take responsibility for making sure that visitors are informed that the Expert is present, but also ensure that the Expert isn't swamped by too many people.

The staff member should also make sure that the Expert has a chance to have breaks where necessary. This may mean that the stand should be overseen by someone else (especially if the equipment is to be left on it) while the Expert is away.

Evaluation:

It is a requirement of the project that all sessions such as this are evaluated using the framework set out by the project. It is a good idea to warn the Expert that this will happen prior to their arrival – and to ask for their help in inviting members of the public to complete evaluation forms etc. The Centre should be willing to share the evaluation data with the Expert as they will probably find it useful in reporting their activities to their supervisors and in reporting research impact to their funders.

Marketing resources

On the CD that accompanies this project, you will find the full marketing pack in electronic form. This includes:

- **Marketing images**
- **Project logos and Partner logos**
- **PowerPoint templates**
- **Text you can use to describe the workshops and the project**
- **Sample press releases**

We are keen that this project encourages people to share, innovate and pushes the field forward. As such we are passionate that the project's resources are shared and made openly available for a variety of people to use. For this reason we have licensed everything under Creative Commons.

Images for your use

To assist you in marketing your workshops and activities to schools and families, and to assist you in getting press interest, we have commissioned photographers to take a series of photos. As part of the project, you are free to use these as you wish (for example, on the web, in print, in PowerPoints, in your annual reports and board presentations). You are also free to give these to media outlets for them to use. The professional photos are of students and adults participating in the activities and experiments, as well as close-ups of the equipment. These photos are supplied in both high-res and low-res formats.

You do not need to credit ASDC or the photographer each time you use our images. We would however want to have both ASDC and STFC mentioned (in full) somewhere in the accompanying text.

Copyrights on materials

All of the project materials, including the handbook, workshops and images (but excluding the logo and hand-drawn illustrations), are licensed under Creative Commons Attribution-ShareAlike 3.0 Unported. This allows anyone to use and share the resources under certain conditions.

The Creative Commons licence means you are free to:

- Share the resources; to copy, distribute and transmit the work
- Remix the resources; to adapt the work

However you can ONLY do this under the following conditions:

- **Attribution**; you must attribute the work in the manner specified by ASDC (but not in any way that suggests that they endorse you or your use of the work)
- **Non-commercial**; you may not use this work for commercial purposes
- **Share Alike**; if you alter, transform, or build upon this work, you may distribute the resulting work only under the same or similar license to this one

For clarification, whilst we would want you to acknowledge and celebrate ASDC and STFC in the text, we are not requiring you to attribute every picture.

Using images from elsewhere

STFC, ESA, CERN, ESO and NASA all have galleries of images that are free for you to use. You must check the specific images for terms of usage, as some may require approval. You can find links to these galleries and specific guidance about their usage on www.exploreyouruniverse.org

Referring to the workshops and shows

You should use 'Explore Your Universe' as the title of all your activities associated with this project.

For example:

- Explore Your Universe: Family show
- Explore Your Universe: Masterclass
- Explore Your Universe: Meet the expert
- Explore Your Universe: Schools workshop

You can use either the main project logo for everything, or these individual specific logos for your marketing, as you choose.

ATOMS TO ASTROPHYSICS

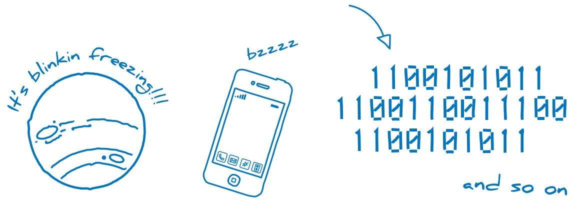
MEET THE EXPERT

FAMILY SHOW

GROUPS

MASTERCLASS

SCHOOLS WORKSHOP



The strapline

The project strapline is Atoms to Astrophysics. This should appear in your text.

ATOMS TO ASTROPHYSICS

ATOMS TO ASTROPHYSICS

When using the strap line, it must always be placed either

- To the right of the title or logo (as above)

or

- Centred beneath the title/logo

When written in text, the strap line should be used as follows, with Capitals

Explore Your Universe: Atoms to Astrophysics

You are not obliged to use the strap line. Use it where you wish.

We hope you will evolve and grow these workshops over time. Therefore, after the first year of your delivery, you may interchange this strapline with the name of your specific new activity, for example, **"Explore Your Universe: Recreating the Big Bang"**.

Sample Marketing Text

You are free to use all or part of this text in any manner you choose. We would want you to mention the Science and Technology Facilities Council (STFC) wherever possible, and to ensure you celebrate their role in the shows and workshops.

Schools Workshop (10-13)

This exciting, curriculum focused workshop uses cutting-edge research by the Science and Technology Facilities Council to help students explore new topics and broaden existing knowledge in science. Using a range of intriguing equipments not usually available to schools, it will allow students to deepen their understanding of fundamental topics such as magnets and fields, electrons and charge and how we observe our Universe.

Through exciting demonstrations and hands-on activities, this workshop will inspire students aged 10-13 with the astounding work of UK scientists and engineers.

Schools Masterclass (14-16)

This exciting, curriculum focused masterclass uses cutting-edge research by the Science and Technology Facilities Council to introduce new topics and broaden existing knowledge in GCSE level Science and Physics. Using a range of astounding equipment not usually available to schools, it will allow students to deepen their understanding of fundamental topics such as fields, electromagnetic radiation, charged particles and how we observe our Universe.

Through exciting demonstrations and hands on activities, this masterclass will bring alive how UK scientists and engineers are at the forefront of scientific advancement in all areas from Atoms to Astrophysics..

Family Show

This exciting, new science show brings alive the latest amazing science being explored by UK scientists and engineers. From discoveries about outer space and our universe, to exploring how light and electricity work, this show might even make your hair stand on end! Come and join us for a highly charged and intriguing 30 minutes. For families and children aged 8 and over to everyone, we explore the world of atoms and particle accelerators, explore how light travels, look at some materials with unusual properties and talk about how we observe our Universe.

Through exciting demonstrations this science show will show families, how from atoms to astrophysics, British scientists and engineers are at the forefront of scientific advancement.

Acknowledging the project

In your online and print publications, you are not obliged to use the Explore Your Universe logo, or images, however you must mention that activity was support by ASDC and STFC.

Press

We have provided a sample press release in the electronic marketing pack. You are free to cut and paste from this to create bespoke press releases to celebrate your role in this national project with your local press. We have also provided you with ASDC and STFC approved boiler plates for use in the 'Notes to Editors'.

We would like to run a co-ordinated national press campaign for the project in early 2013 as the first centres begin to deliver activities with schools and families and will send you a sample press release at that time.

In the first months of the project you must seek approval for any press release that mentions the project by sending your draft press releases to the project manager: **michaela.livingstone@sciencecentres.org.uk**

Please give the website address wherever possible: www.exploreyouruniverse.org

Talking about the project

Online, we would want you to mention that activity was support by ASDC and STFC (use the names in full) and add our logos. For print we ask you to include this (especially the logos) where at all possible.

We would be keen that you use the Explore Your Universe logo and web address where possible.

Text to use

Below are 4 separate paragraphs of approved text for you to use:

"This project is a partnership between the UK Association for Science and Discovery Centres (ASDC) and the Science and Technology Facilities Council (STFC)."

"Explore Your Universe is a two year national, strategic partnership between the UK Association for Science and Discovery Centres (ASDC) and the Science and Technology Facilities Council (STFC). The project brings together some of the most fascinating and diverse science in the country with the talents and infrastructure of the nation's largest network of science engagement organisations.

The project aims to inspire more young people across the UK with the wonders of the physical sciences by sharing the amazing stories and technologies of STFC.

Overall, the programme is providing a series of exceptional hands-on activities, experiments, schools workshops, public shows, meet-the-expert sessions and a variety of other events, all focussing on STFC science and giving young people the confidence, curiosity, and interest to continue to explore and ask questions long after they leave the science and discovery centres. This national project will be led by ASDC in collaboration with The National Space Centre in Leicester and Jodrell Bank Discovery Centre in Cheshire."

Social Media

We would be delighted if you would post pictures, comments and videos on to the Facebook page, and encourage your visitors to do the same.

www.facebook.com/pages/explore-your-universe/441870042517559

(or just search 'Explore Your Universe')

When using twitter, if possible, please use the hashtag **#exploreyouruniverse**

We'll be tweeting from: **@Atoms2Astrophys (ExploreYourUniverse)**

Further information on the project's social media and press campaign will be given at the training academies and on the website.

The Brand Identity

Our Logo

We use our logo for all internal and external communications.

This includes in-house staff communications, stationery, forms etc. As well as advertising and direct marketing.

Our wordmark is made from specially drawn characters so it can't be replicated from a standard typeface.

Always use the artwork that is available from the Project Manager when using our logo.

Email **michaela.livingstone@sciencecentres.org.uk** or download from the resource section on our website: **www.exploreyouruniverse.org**

Main identity

Use with care

Our logo has been designed to be used as a strong communications device that can work well on all types of media large and small.

Do not alter the appearance of this logotype, either by distortion, special effects or by any added features.

Use this logotype consistently on all communications. Doing so will help create awareness, understanding and recognition.

Logo Versions

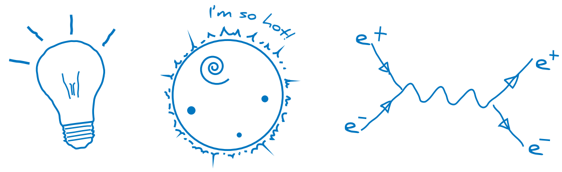
The full colour logo should be used whenever possible and the black version should only be used if you are printing in black and white.

The white negative logo should only be used on solid blocks of any of the brand colours.

Full colour positive logo

Black and white positive logo

White negative logo



Clear space and size

To ensure clarity and impact it is important not to crowd the logo with text or images. Always ensure there is a clear space between the logo and other elements equal to the width of the **X** in E**X**PLORE.

To maintain legibility, the logo cannot be reproduced below a minimum size of 25mm wide.

Minimum logo exclusion zone

Logo minimum size

Brand colours

Colour and its use is an integral part of our brand expression.

There are two primary colours and five secondary colours which help to create a sense of diversity and bring life to the brand. All colours can be used. However the main brand colours are the blues.

The use of black is advised for body copy only.

Primary colours

Pantone 296C
CMYK = 100/46/0/70
RGB = 0/45/86

Pantone 2935C
CMYK = 100/46/0/0
RGB = 0/118/192

Secondary colours

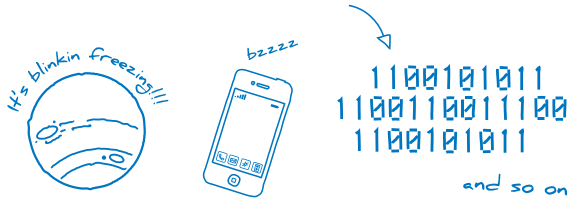
Pantone 227C
CMYK = 0/100/7/19
RGB = 198/0/111

Pantone 520C
CMYK = 64/100/12/0
RGB = 124/43/131

Pantone Warm Red C
CMYK = 0/75/90/0
RGB = 242/101/49

Pantone 321C
CMYK = 100/0/31/23
RGB = 0/140/153

Pantone Warm Gray 9C
CMYK = 0/11/20/47
RGB = 154/139/125



Fonts

The Explore Your Universe font for all professionally printed materials is Omnes, designed by Joshua Darden at dardenstudio.com. It has been chosen for its friendly, approachable yet individual appearance.

The Omnes weights displayed for use are below:

Omnes regular – use for body copy

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 0123456789

Omnes semi bold – use for headings, sub headings and emphasis at body copy sizes only

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 0123456789

For in-house documents Arial has been chosen for its ease of use and compatibility.

Arial regular – use for in-house body copy

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 0123456789

Arial bold – use for in-house headings, sub headings and emphasis at body copy sizes only

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz 0123456789

Glossary

A-Z Glossary

Alloy – a mixture of two or more materials that combines properties of both

Alpha particle – a particle made from two protons and two neutrons. They are released from certain radioactive elements in the process of radioactive decay

Argon – an inert element, usually found as a gas

Asteroid – a body of rock and/or metal ranging in size from a few kilometres to a few hundred kilometres across that generally orbits the Sun. In our Solar System asteroids are mainly found between the orbits of Mars and Jupiter

Atoms – originally thought to be the basic building block of all matter but we now know they are made up of smaller particles

Beta particle – an electron. They are released from certain radioactive elements in the process of radioactive decay

Boson – a particle which obeys Bose-Einstein statistics. All particles have a property called spin and in the case of a boson this must be an integer (whole number). Examples of bosons are photons (particles of light), particles that carry forces such as gluons (carrying the strong nuclear force) and the Higgs boson which gives particles mass

Charged particle - an elementary particle, such as a proton or electron, with a positive or negative electric charge

Coherent – when referring to light, coherence is when the phases of all electromagnetic waves at each point on a line perpendicular to the direction of the beam are identical, this means that all the light waves in the beam are in phase (their peaks and troughs line up). This is most commonly observed in laser light

Collimated – when referring to light, collimated means the light waves are restricted in size in two dimensions but not the third; made into a pencil like shape

Comet – a body consisting of frozen gasses (chiefly ammonia, methane and carbon dioxide), water and dust which are only observed when orbiting the Sun on a highly elliptical orbit

Conductivity – how easily a current can flow, or how easily heat can be transferred, through a material

Coronal mass ejections – a stream of high energy charged particles ejected from the Sun, usually after a solar flare

Dark matter – matter in the universe which we theorise is there from the gravitational effect it has but we can't see

Detector – an electronic device that can register the presence of particles, radiation or any other measurable phenomena and translate this into a visual representation

Dewar – an insulated container for storing cold liquids such as liquid Nitrogen

Electromagnetic wave – any of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays

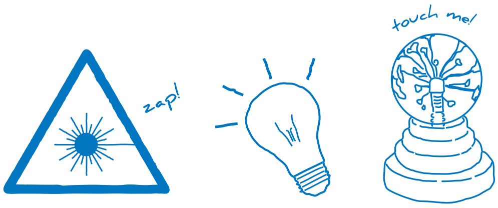
Electrons – small negatively charged particles which orbit the nuclei of atoms

Element – a substance made only of a single type of atom. There are 118 different elements and these make up the periodic table at present, however new elements are occasionally discovered

Energy – the capacity or power to do work, such as the capacity to move an object (of a given mass) by the application of force. Energy can exist in a variety of forms, such as electrical, mechanical, chemical, thermal, or nuclear, and can be transformed from one form to another but cannot be created or destroyed

Fusion energy – the energy released when two atoms fuse (join) together to make one heavier atom

Gamma radiation – a high energy photon. They are released from certain radioactive elements in the process of radioactive decay



Granulations – bright regions (approximate diameter 900 km) having a fine speckled structure that can appear briefly on any part of the Sun's surface

Grounded – attached to the Earth. In terms of electricity this means that electrons will preferentially travel to the Earth rather than through you

Half-life – the amount of time it takes half of a radioactive element to decay

Hydrogen-alpha – a narrow wavelength band of visible light. Solar telescopes contain a hydrogen-alpha filter that will allow this range to pass through, but block out other wavelengths of light, reducing the dangerous intensity

Impactor – an object that will, or has, collided with another object

Insulators – a material that does not easily allow electrons, or does not easily allow the transfer of heat energy, through it

Ion – an atom with electrons either added or removed so that it has an overall charge

Ionise – to excite electrons, enabling them to escape the atom leaving it with an overall charge

Ionising – something which can ionise an atom

Isotopes – atoms of the same element (defined by the number of protons) with different numbers of neutrons and therefore different masses

Laser – a device that emits coherent light. Coherence is when the phases of all electromagnetic waves at each point on a line perpendicular to the direction of the beam are identical, this means that all the light waves in the beam are in phase (their peaks and troughs line up)

Lepton – one of the most fundamental types of particles we know of (the others are quarks). There are six types of lepton. The most common form of lepton is the electron

Magnetic field – a field of force produced by moving electric charges, electric fields that vary in time, and by the 'intrinsic' magnetic field of particles associated with the spin of the particle

Magnetic flux – a measure of the amount of magnetic field passing through a given surface

Magnetic Pole – in terms of magnets, pole refers to one of the two ends of the magnet from which magnetic field lines emanate from, or enter, the magnet

Magnetised – something that produces a magnetic field, either permanently or temporarily

Meteor – the visible path of a meteoroid as it travels through a planet's atmosphere

Meteorite – a meteoroid which impacts the surface of a planet

Meteoroid – a sand grain to pebble sized particle of debris in the Solar System

Molecule – at least two atoms bonded together

Moon – a naturally occurring object orbiting a planet

Muon – a heavier version of an electron

Nano-particles – particles that are so small they are measured on a nano scale (1 millionth of a millimetre)

Neutrons – one of the particles which make of the nuclei of atoms. They have no charge

Nuclear fission – atomic nuclei breaking apart to produce energy. This only works for nuclei which are relatively large

Nuclear fusion – atomic nuclei joining together to produce energy. This only works for nuclei which are relatively small

Nuclear radiation – alpha, beta and gamma particles (defined elsewhere)

Nucleus – the central region of an object. In the case of an atom this consists of protons and neutrons, and electrons orbit the nucleus

Observatory – a place where objects are observed. This normally means a place where there are telescopes to observe things in space

Orbit – to move around an object in a circle (or other closed shape)

Ordinary matter – everything in the Universe which we can detect (not dark matter)

Oscillating – moving up and down, or side to side e.g. a pendulum

Oxide – a compound which includes Oxygen

Particle physics – the physics of the most fundamental particles in our universe

Particles – no exact definition; this can mean atoms, molecules, sub-atomic particles, etc

Phase – the fraction of a complete cycle elapsed as measured from a specified reference point and often expressed as an angle

Photon – a bundle of light energy which behaves as a particle with no mass

Planets – an object which is large enough to hold itself in a spherical shape by its gravity, has cleared its orbit of other objects and which orbits a star

Plasma – the fourth state of matter (the other three are solid, liquid and gas). It is like a super heated gas which has become ionised due to the energy in it

Polarised – oscillating in a specific direction, as opposed to random directions

Proton – one of the particles which make of the nuclei of atoms. They have positive charge

Quark – one of the most fundamental types of particles we know of (the others are leptons). There are six types of quark. Protons and neutrons are made of quarks

Radiation – in terms of the electromagnetic spectrum, radiation refers to a wave of energy with a particular wavelength and frequency. In terms of radioactive decay, radiation is the products of the decay which radiate away from the nucleus

Radioactive decay – the process by which a nucleus breaks down and forms new daughter particles, releasing radiation in the process

Satellite – natural, artificial – a natural satellite is more commonly known as a moon. An artificial satellite is what we mean by the everyday use of the word satellite

Solar flares – massive outpourings of energy from a particular location on the sun, commonly associated with regions of intense magnetic field strength

Solar prominences – small arcs and shapes emanating from the surface of the Sun

Solar system – a collection of planets orbiting a star

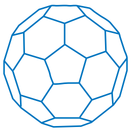
Star – a large sphere of gas under high enough pressure for nuclear fusion to have started

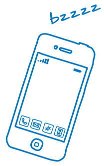
Static electricity – electric charge that has accumulated on an object

Sub-atomic particle – a particle which is smaller than an atom

Sunspots – areas on the surface of the Sun which are cooler than the rest of the surface

Super-saturated – an extremely concentrated vapour that is in a delicate balance between remaining in vapour form and condensing into liquid form





Telescope – an optical device used to gather light and magnify the light (from all parts of the electromagnetic spectrum) from distant objects

Tendrils – wispy lines that emanate from the centre of a plasma ball

Vapour – particles of moisture suspended in air and visible as clouds or smoke

Vapourised – to be converted into vapour

Velocity – the vector form of speed. Velocity has a magnitude and a direction whereas speed only has magnitude