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

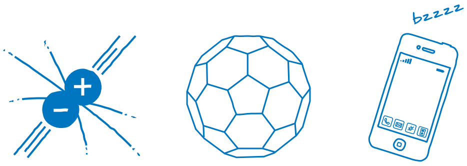
- Bar magnets and observing of magnetic fields
- Interaction of magnetic fields and their uses

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

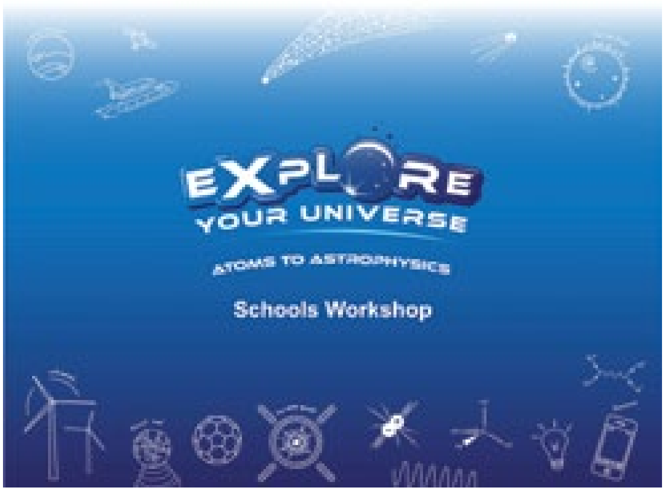


Notes

EXPLORE YOUR UNIVERSE

PowerPoint Presentations

10 - 13 Schools Workshops

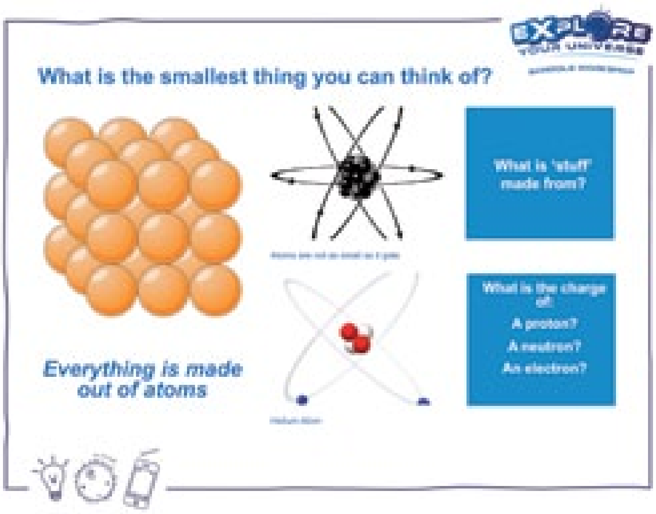


Slide 1 - Notes

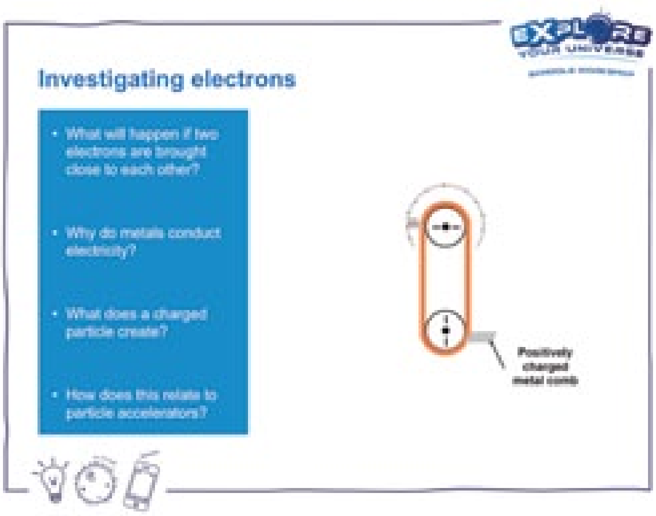
Slide 2 - Notes

Slide 3 - Notes

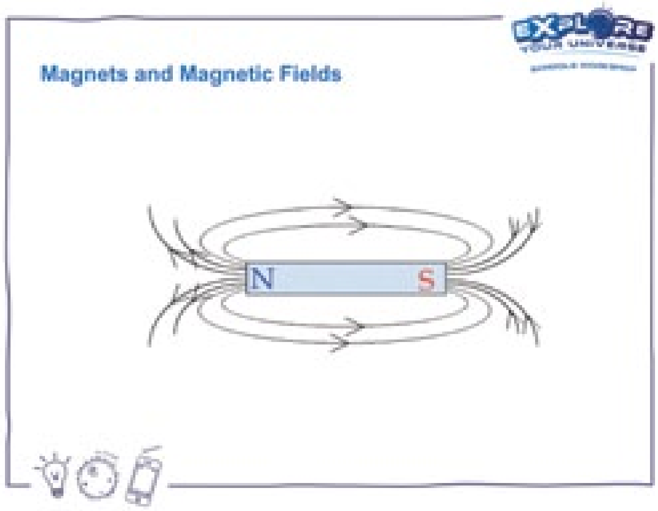
Slide 4 - Notes



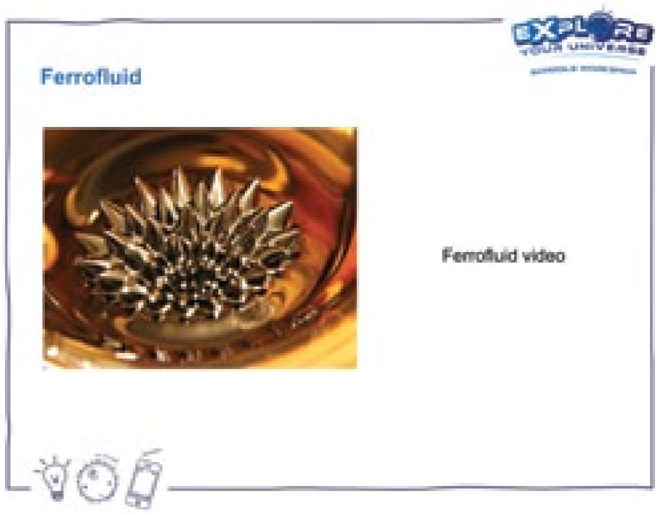
Slide 5 - Notes



Slide 6 - Notes

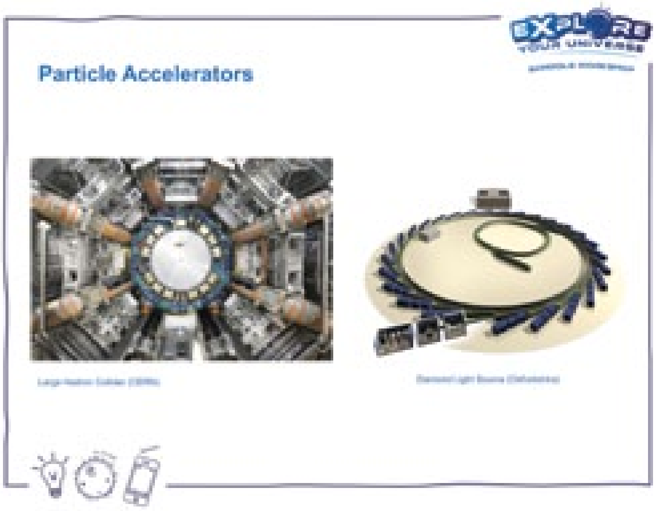


Slide 7 - Notes



Slide 8 - Notes

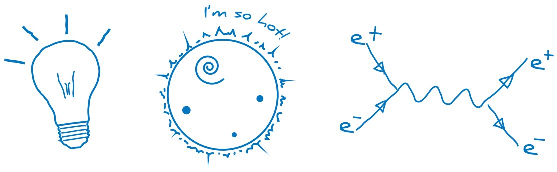
Slide 9 - Notes

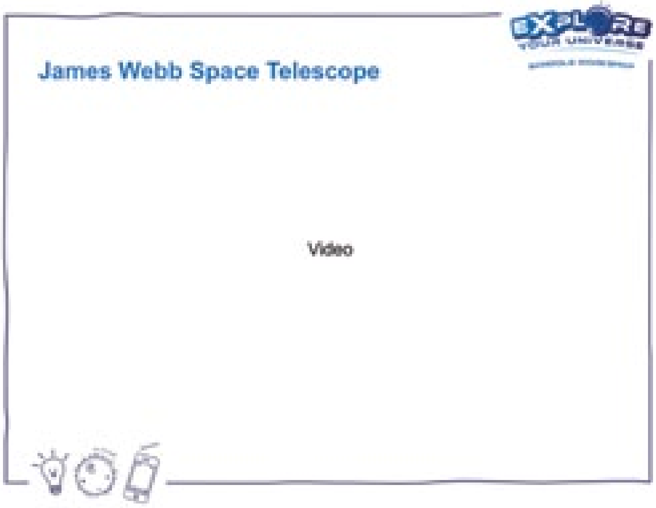


Slide 10 - Notes

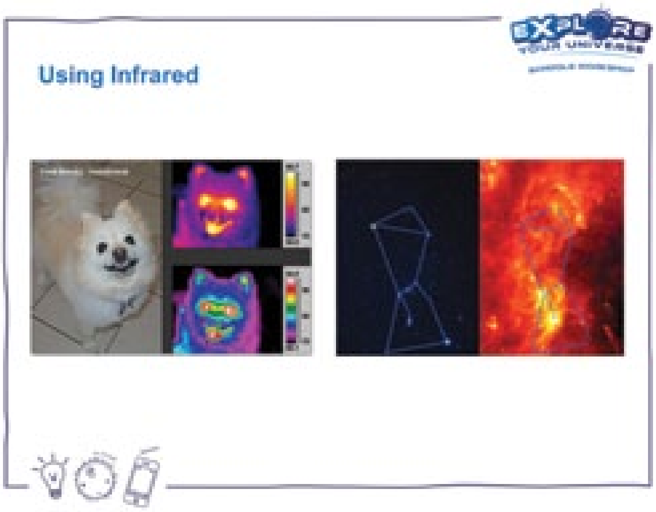
Slide 11 - Notes

Slide 12 - Notes





Slide 13 - Notes



Slide 14 - Notes

Slide 15 - Notes

Notes

EXPLORE YOUR UNIVERSE

Age 14 - 16, 2 Hour Masterclass

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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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.

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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.

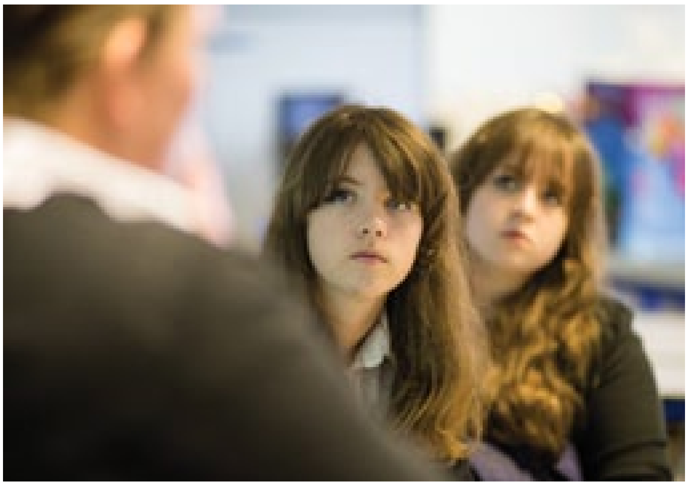
How can scientists use this part of the EM spectrum to find out even more about our Universe?

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.

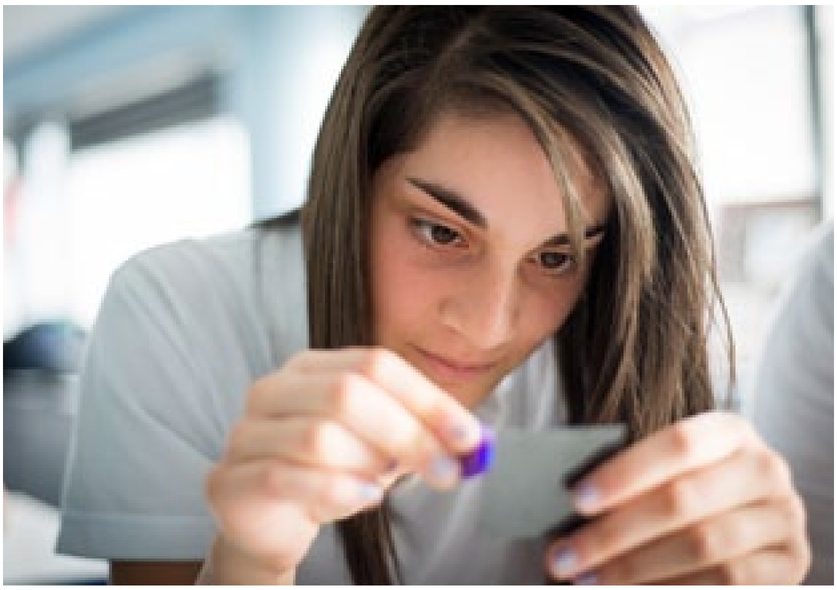
STEREO is an ambitious mission using two solar observatories to monitor the Sun and the region between the Sun and the Earth. The two identical probes are offset from one another, one flying ahead of the earth in its orbit and the other behind the earth. The spacecraft look back at the sun and the space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

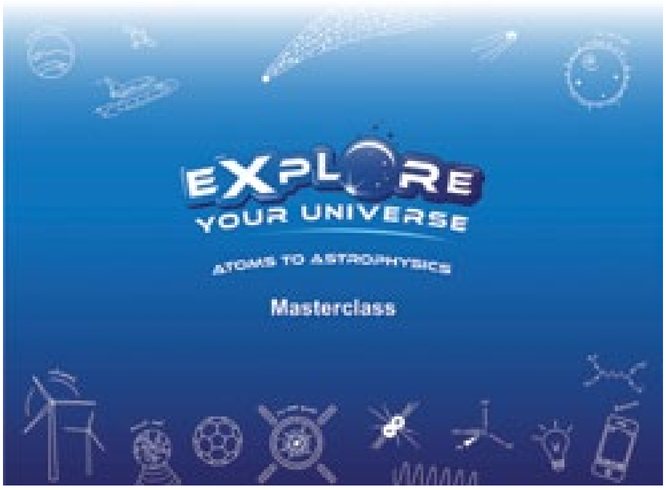
- Structure and size of an atom
- Subatomic particles and their properties
- Radiation – alpha, beta and gamma radiation, radiation properties and how to observe radiation through the use of a cloud chamber

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

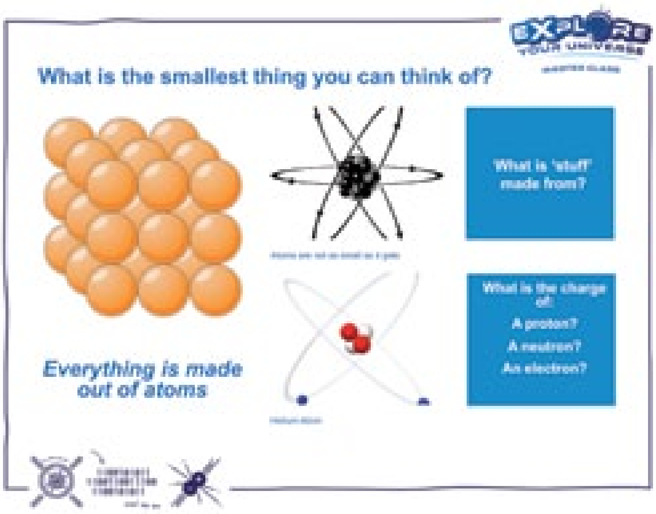


Slide 1 - Notes

Slide 2 - Notes

Slide 3 - Notes

Slide 4 - Notes



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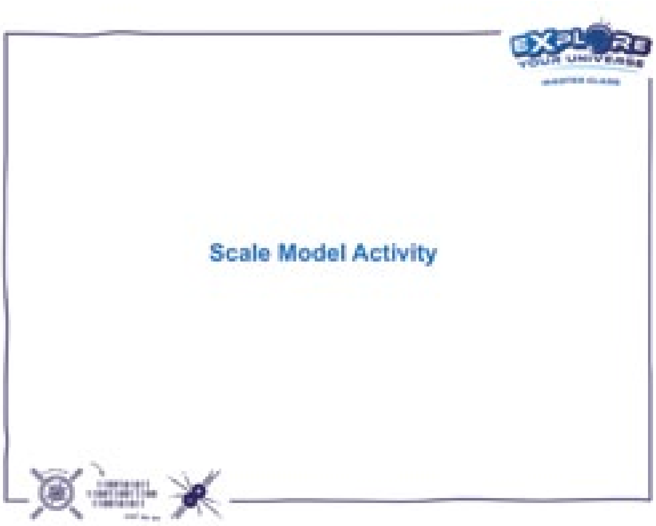

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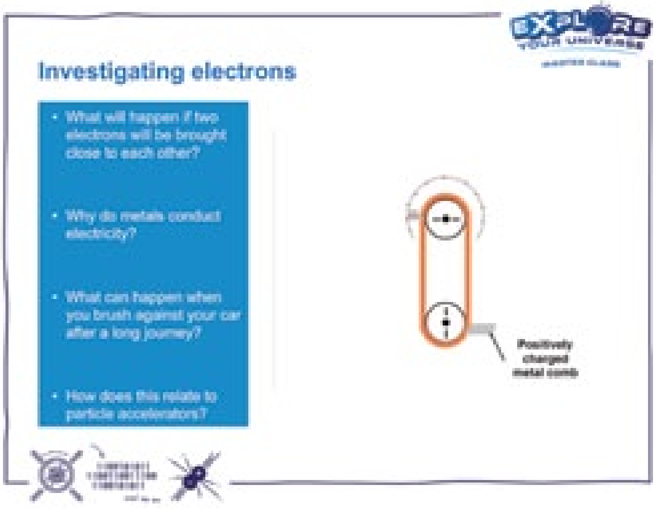

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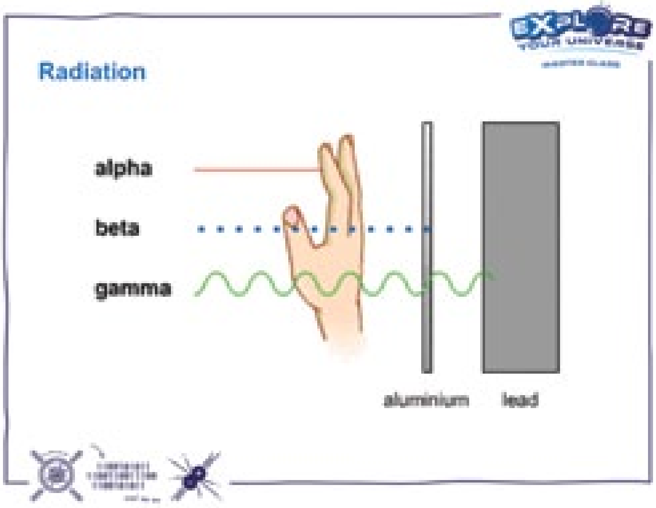

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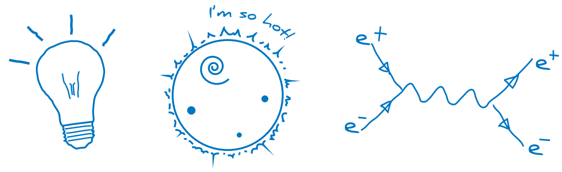

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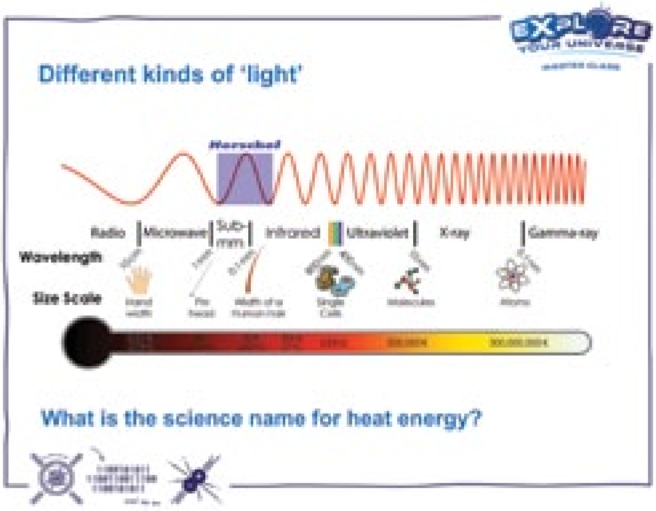

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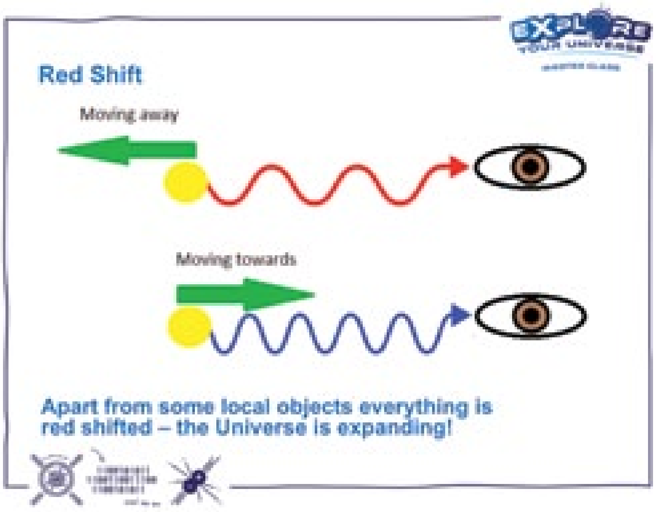

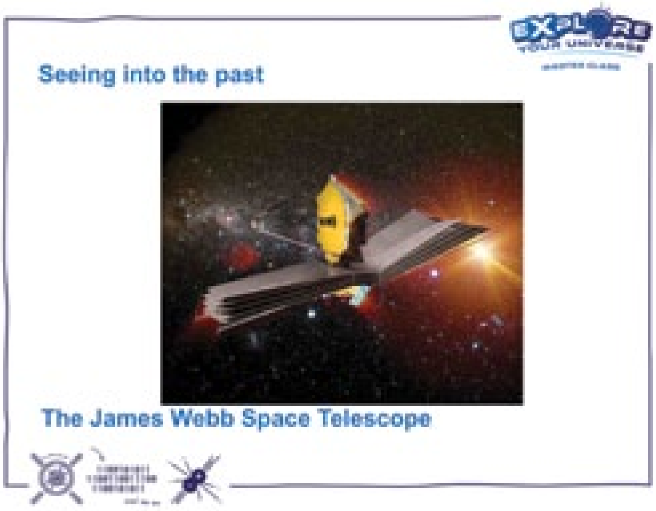

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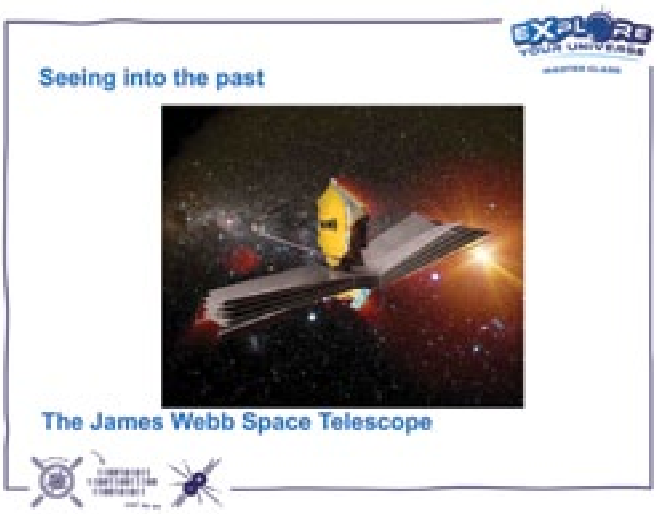
Slide 17 - Notes

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

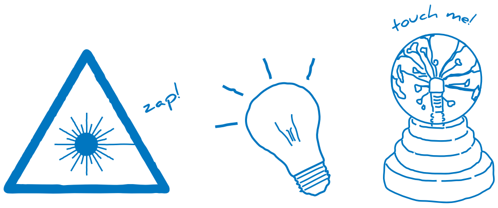
This 30 minute show is aimed at an audience of families with children between the ages of 8 and 13. The content and show length may therefore not be suitable for very young children.

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.

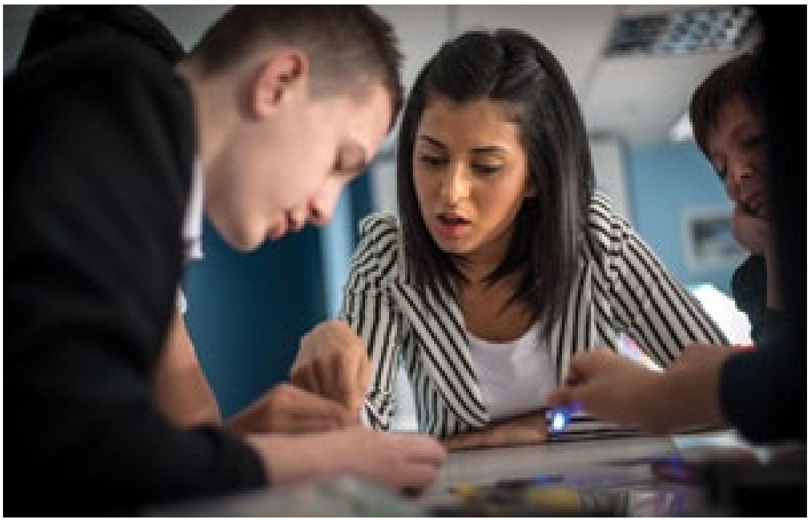
This sheet assumes you have already found an Expert and agreed a time and place for the session to take place. Advice on how to go about this will have been given in the training academy.

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.