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 (in metres per second) = wavelength (in metres) x frequency (in 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?

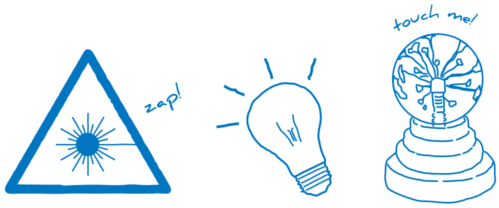
The Sun is a star – a ball of gas and plasma powered by nuclear fusion in its core. At 150 million km distance, a solar telescope is needed to see it in any detail.

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.

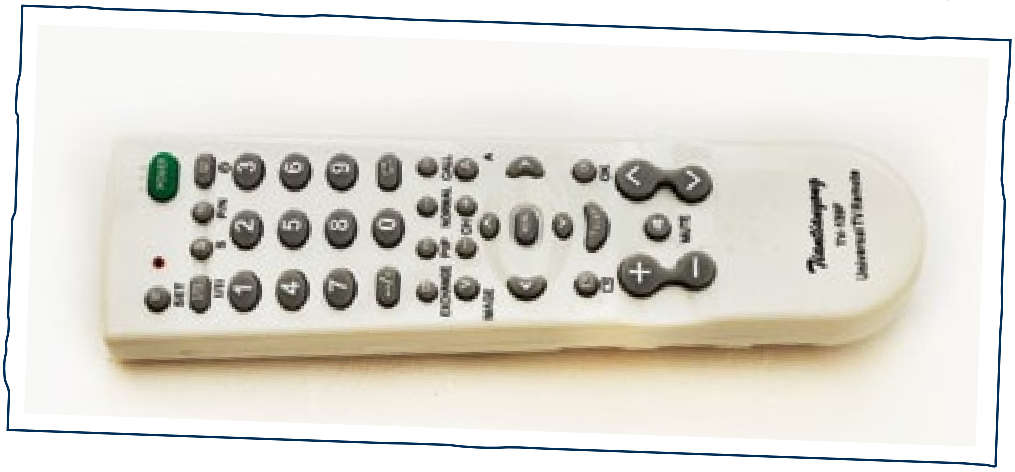
Ultraviolet light is also produced by synchrotron light sources, such as the Diamond Light Source in Oxfordshire. The Ultraviolet beamline at the Diamond Light Source is used to look at the structure of proteins and the way drugs might interact with them in order to develop new drugs.

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!

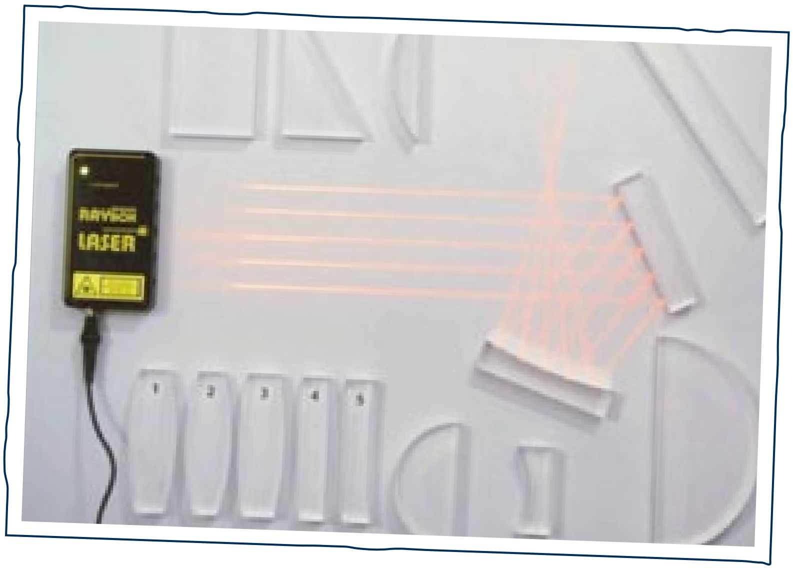
Fibre optic communications were originally developed for scientists. Experiments that collect large amounts of data such as arrays of telescopes (e.g. e-MERLIN at Jodrell Bank and around the UK) and particle physics experiments (such as the detectors for the LHC) need fast connections in order to send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

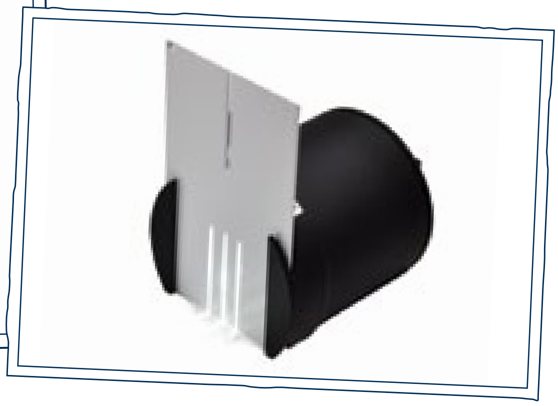
To get round this problem the reflecting telescope was invented. This just uses a curved mirror to focus the light and this focus works independently of the wavelength of the light. Both refracting and reflecting telescopes are in use to this day but reflecting telescopes do have this advantage over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

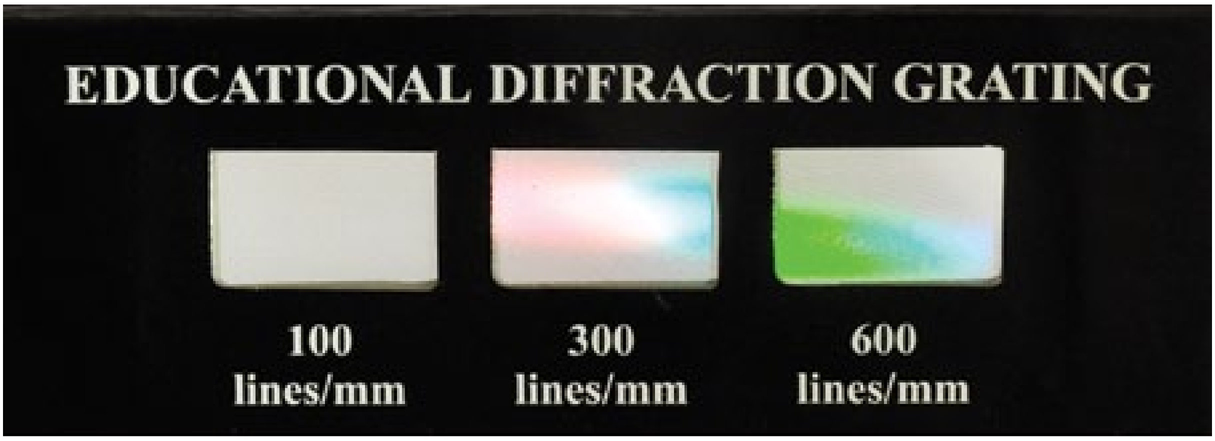
Once this is done there may be some time to hand out some blank pieces for students to draw their own UV art on.

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?

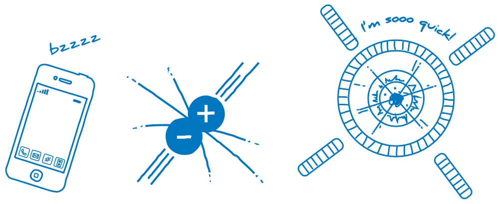
Diffraction is the bending (change of direction) of waves when they encounter an obstacle. It can be thought of like water being squeezed through a small gap and then spreading out once it is through the gap.

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.

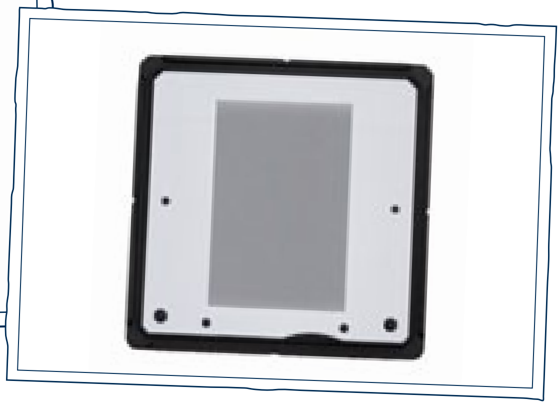
This crystallography technique is used widely on the beamlines of synchrotron light sources such as STFC'S Diamond Facility. The predecessor to Diamond was the SRS (Synchrotron Radiation Source) which was based at STFC's Daresbury Laboratory in Cheshire. Cadbury's used one of the beamlines on the SRS 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.

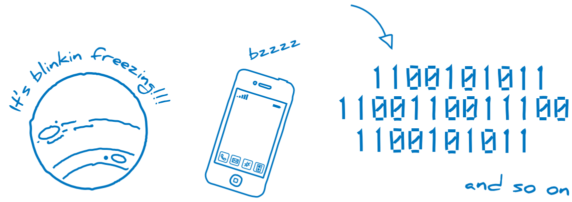
1) Why is it called aerogel?

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

Meteorites

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.

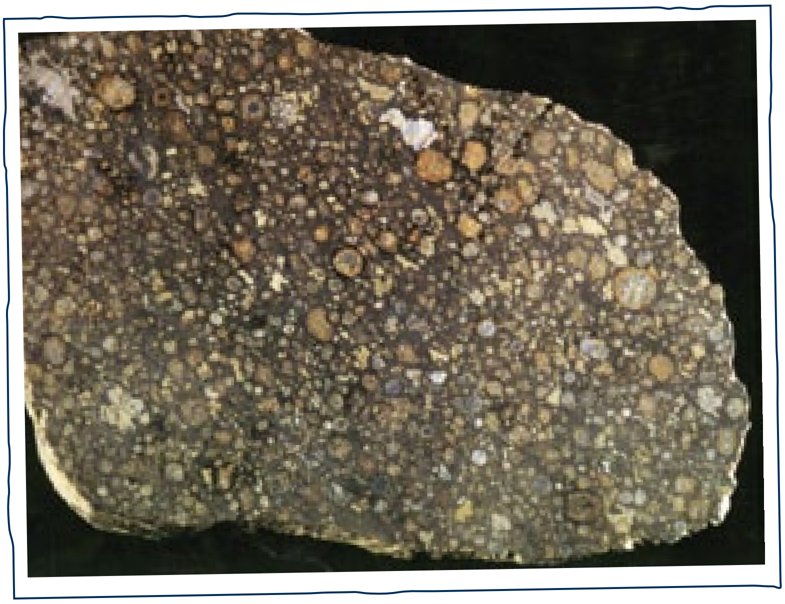
2) Visual inspection

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

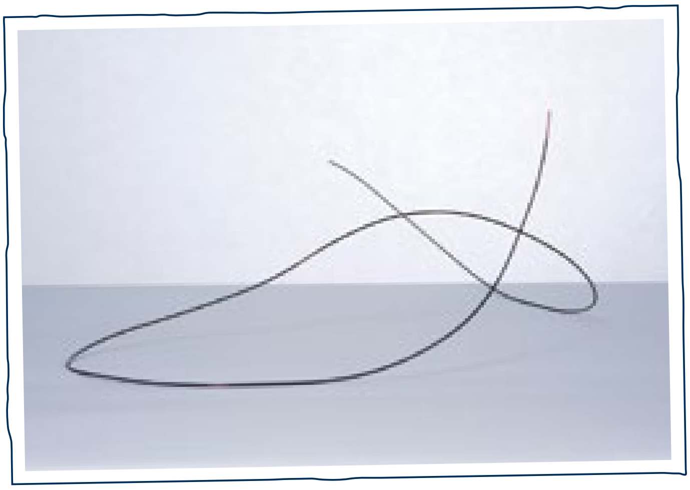
Studying meteorites give us an insight into the formation of the solar system, as well as information on the geology of space and other planets. STFC funded researchers at the Open University's Planetary and Space Sciences Research Institute to examine these intriguing clues to the origins of our own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

Extra resources

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

Notes

Equipment Briefing Sheet / 18



← 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.

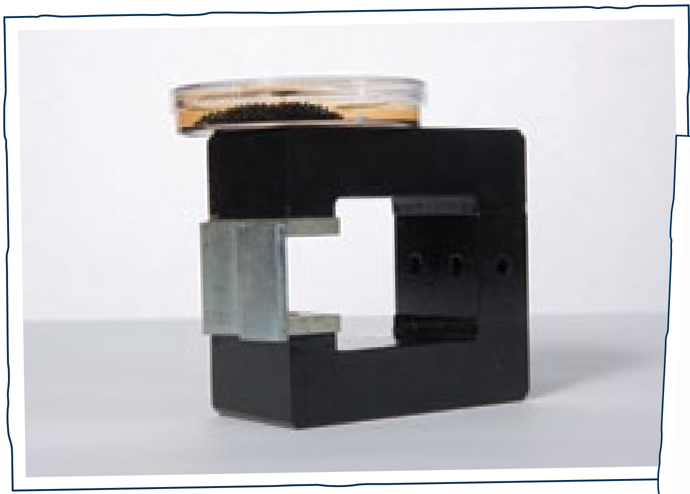
Memory metal can be 'reset' to return to any shape in its austenite phase by heating it to over 500 degrees Celsius and allowing it to cool slowly. This means that for future space telescope missions involving large arrays of mirrors which need to be unfurled to create one large diameter mirror, memory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



Ferrofluid

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.

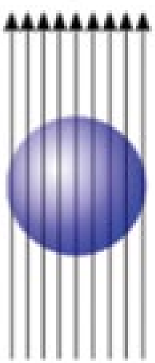
*The Kelvin is the primary unit of temperature measurement in the physical sciences and unlike the degree Celsius scale is not referred to (or typeset) as a degree.

Experiments to try

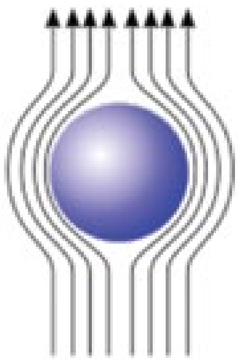
The two demonstrations are designed to show magnetic phenomena associated with superconductors which have direct applications to STFC-supported science.

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

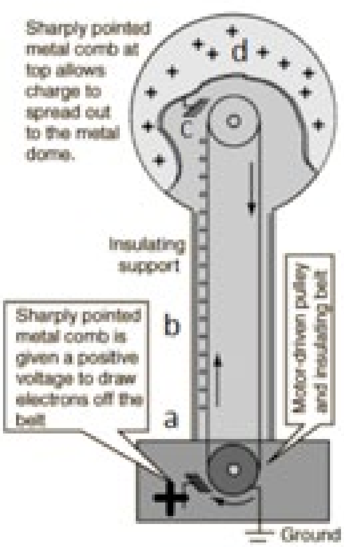
1) What is a magnet?

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.

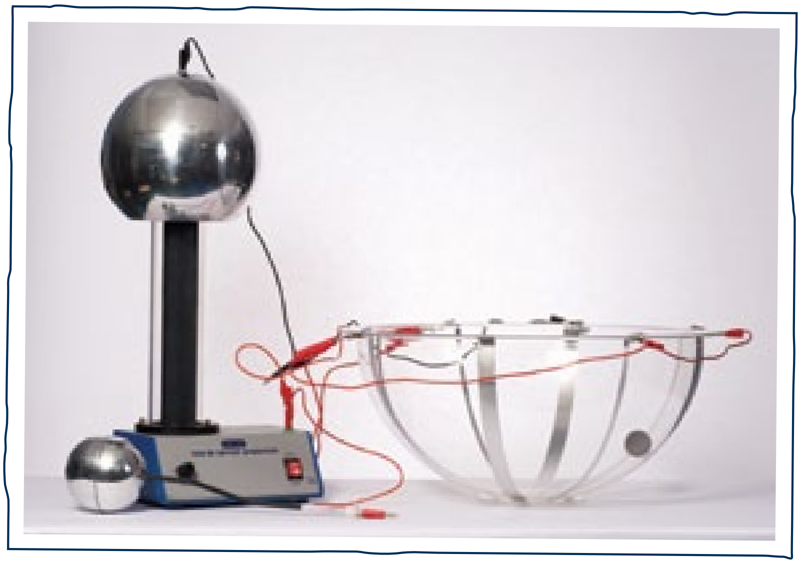
However particle accelerators all began with the Van de Graaff generator, and through those early experiments with static electricity, accelerating charges and building bigger and bigger voltages, the science of particle physics began.

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

Notes

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?

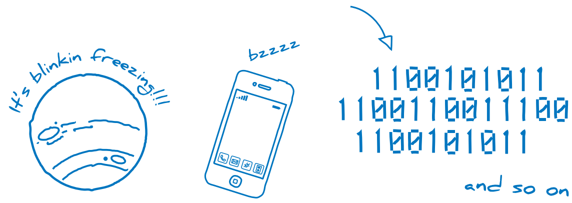
The boiling point of liquid Nitrogen is -196°C. If the liquid Nitrogen is exposed to temperatures higher than this it will boil and turn back into a gas. Therefore, it needs to be stored in a very well insulated container to keep it a liquid. The dewar has a special lid to allow for expansion. Never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

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.

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