Energy Efficiency

Teacher Resource Pack

Energy Efficiency
Teacher Notes

Suitable for: 11-16 year olds
Location: Science laboratory or classroom
Length of session: 1 hour

Activity Introduction

This activity combines a series of investigations and demonstrations that introduces students to the electromagnetic spectrum, and highlights how energy can be wasted in unseen ways. Practical sessions will involve using different light sources to visualise ultraviolet and infrared light, making spectroscopes to compare incandescent and fluorescent lightbulbs, and studying fluorescent light. The session culminates with students demonstrating the knowledge they have gained via presentations in various formats.

Learning Outcomes

During this session, students will:

- Understand that visible light is part of the electromagnetic spectrum
- Demonstrate the presence of ultraviolet (UV) and infrared (IR) light using a UV lamp and an IR camera
- Make and use a small spectroscope to investigate the differences between incandescent and fluorescent bulbs
- Demonstrate the principle of fluorescence using a compact fluorescent (CFL) lightbulb and a plasma ball

Energy Efficiency: Invisible Light Activity
Teacher Notes

Introduction

When running the Invisible Light practical session, you might wish to consider setting up a “circuit” of work stations for the various activities as some will be open to student investigation, whilst others will need to be demonstrated by a member of staff.

Demonstrations involving ultraviolet (UV) and infrared (IR) light are intended to make the students aware that invisible light is actually all around us, but requires special equipment to detect it.

The activity that involves making and using a spectroscope enables students to investigate a light source by viewing the spectra that it emits. Finally, the demonstration of lighting a compact fluorescent lightbulb (CFL) using a plasma ball can help students to understand how light is created efficiently through fluorescence.

Equipment Required

- Modified IR webcam (see information below)
- IR torch
- UV lamp & UV pen
- Fluorescent glow sticks
- Spectroscope templates
- Spectral film squares
- Plasma ball
- Lamp with incandescent bulb
- Lamp with compact fluorescent (CFL) bulb
- Scissors
- Sellotape
- Glow sticks
- 2 litre bottle of Cola
- Banknote ***Note to Uniscience: For this session we use a £5 bank note. It will be necessary for you to test the appropriate section of the activity with local currency**
- Computer for the web camera
- The room used must be able to be blacked out, e.g. with good blinds

<u>How to modify the webcam</u>

For some of the demonstrations run in this session, you will need to use with a modified webcam that has had its IR filter removed, thus allowing you to see the IR light. In order to block out optical (visible) light, two polaroid filters can be placed over the lens of the webcam. Most inexpensive webcams can be modified, and we generally use Sogatel USB webcams.

- Pull apart the casing of the webcam, using a small screwdriver to help if necessary.
- The contents of the webcam can now be removed – try to remember where they originally came from
- Remove the plastic ring from around the front lens and unscrew the front lens from the circuit board
- The IR filter is a very small square of red glass on the back of the lens assembly which should be snapped out with a very small screwdriver (as this will create glass dust, it is recommended to wear lab coat, gloves and safety goggles)
- Now reassemble the webcam back to its original state
- In order to block out optical light, take the two pieces of polaroid filter cut them into small circles, big enough to cover the lens of the camera.
- Rotate one filter 90 degree, they should now look opaque, and tape the two pieces together
- The filter can now be either held over the lens on the rebuilt webcam, or taped over the lens on the outside of the webcam

Procedure

Below is a list of the various demonstrations that can be used for a carousel of activities linked to invisible light and energy efficiency. They can be performed in any order.

It is highly recommended that you test all of the demonstrations before the session to ensure that they run smoothly.

An educational video has been developed to compliment this activity and can be accessed at: https://vimeo.com/139342553 (password: teach15)

Ultraviolet and Infrared light

Objective: demonstrate the presence of ultraviolet and infrared light using an IR webcam and a UV lamp

Before the session you must set up the IR webcam with your computer, installing the webcam software from the CD if necessary.

- Turn the IR torch on – it won't look bright at all. Close the blinds, switch off the lights and hold the IR torch next to the web cam. Use the IR torch and webcam to show the room in infrared: you should be able to see the room clearly on the screen even though everywhere is dark to your eyes!

- Put the bottle of Cola in front of the webcam – you'll be able to see through it!

- Put the banknote in front of the webcam and look at the Queen's face – half of it will be missing. Some of the note is made using ink that does not absorb IR light! **Note to Uniscience: this section may need to be modified/removed, depending on whether local currency works for the activity**

- Use the UV lamp with the banknote and UV pen to demonstrate how inks can be used that are sensitive to UV light. They absorb the UV and emit it again at a wavelength you can see – this makes it look like the ink is glowing!

Spectroscopes

Objective: make and use a small spectroscope to investigate the differences between incandescent and compact fluorescent bulbs

The following investigation required the use of spectroscopes, which the students should make. If your school has discharge tubes filled with H_2, He, or Ne, you might use these as part of the investigation, but they are not provided in the kit.

- Assemble the Spectroscopes, scoring carefully along the indicated lines and sticking the flaps on the **OUTSIDE** of the device to keep the inside as dark as possible. The spectral film goes over the circular hole, you may need to rotate it 90° to view the spectra properly

- Introduce the idea of energy efficiency and explain why we now use fluorescent lightbulbs. Explain that there are many types of light emitted by an incandescent light bulb that you cannot see

- Get out the two lamps and show how the brightness of them is comparable, although they use different light bulbs

- Point the completed spectroscopes at the two lamps (incandescent and fluorescent bulbs) and note the differences between them.
  <u>Optional extra: try photographing the spectra by putting a camera to the eye-hole of the spectroscope</u>

- You could add an extra experiment investigating the heat given off by both bulbs from a set distance – perhaps by trying to heat water. The incandescent bulb will give off a lot more heat – this is wasted energy!

- Finally, point the IR web cam at both lamps – they should look roughly as bright as each other to the eye, but when you look with an IR camera the incandescent bulb is far brighter. You can't see this IR light, which is not much use for a lightbulb, so this is all wasted energy

<u>Fluorescent light</u>

Objective: demonstrate the principle of fluorescence using a CFL and a plasma ball

- Explain that fluorescent bulbs give off light when the electrons are excited by an electric field.
  Optional extra: use an atomic model to explain that electrons can only jump from one energy level to another and this is what results in the very specific wavelengths emitted

- Demonstrate that a fluorescent lightbulb needs only a small amount of energy to light up. Switch the plasma ball on and bring the spare CFL lightbulb close to it – it will light up!

- Let the students investigate the light produced by the glow sticks

Debrief

At the end of this session it would be beneficial to recap the following learning objectives:

- Understand that visible light is part of the electromagnetic spectrum
- Demonstrate the presence of ultraviolet (UV) and infrared (IR) light using a UV lamp and an IR camera
- Make and use a small spectroscope to investigate the differences between incandescent and fluorescent bulbs
- Demonstrate the principle of fluorescence using a compact fluorescent (CFL) lightbulb and a plasma ball

After the experiment is complete, please make sure that the lamps and the camera are packaged “snugly” to prevent them moving around too much. Use a space filler, such as rolled up paper towels to help prevent damages.

Health and Safety

Risk assessment: A risk assessment appropriate for this practical activity is included in the Teacher Resource Pack. Please ensure that you read this completely and consult your school’s health and safety officer with any concerns.

Material & Safety Data Sheet (MSDS): No MSDS is required for this activity as no chemicals are used.

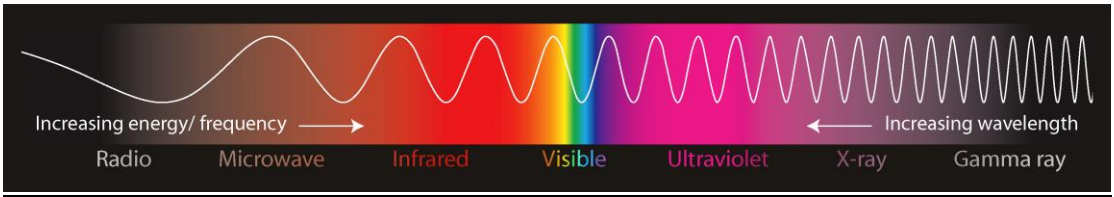
Energy Efficiency
Student Worksheet

Introduction to Energy Efficiency

Using energy efficiently is as important as generating it cleanly in the first place. We say that a process is efficient if most of the energy that goes into it is used in an effective way. Identifying where energy is used inefficiently is not easy as the wasted energy is often hidden. For example, running a typical car generates 100,000J of energy from a petrol engine, however only 38,000J is utilised as kinetic energy, 2000J for lights, radio and recharging the battery and 60,000J (60%) of the energy is wasted as excess heat and sound.

The Electromagnetic Spectrum

The electromagnetic spectrum is the distribution of electromagnetic radiation as a continuous range of electromagnetic wavelengths of different frequencies, as depicted in the image below. The spectrum extends from radio waves with short wavelengths and low frequencies to gamma ray waves, which have short wavelengths and the highest frequencies. Visible light only makes up a small percentage of the electromagnetic spectrum, with the remaining portions being invisible to the naked eye.



Visible light is only a very small portion of the electromagnetic spectrum
(Image reference: https://filmlessradiography.files.wordpress.com/2012/04/electromagnetic-spectrum_inverted_web.jpg)

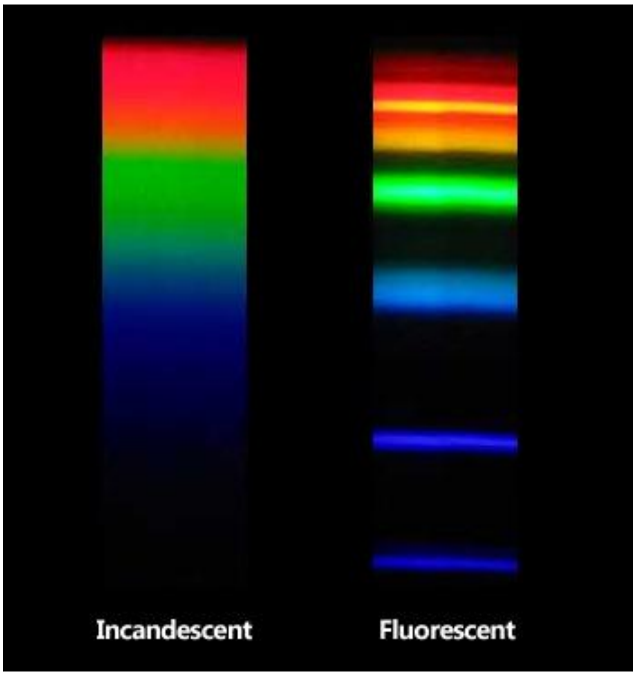
We can use the invisible parts of the electromagnetic spectrum to analyse processes for energy efficiency. The image below, for example, is of a house taken with an infrared camera: areas that are red or yellow in colour, including some of the ground floor windows, the roof and the chimney, are emitting a lot of infrared light which suggests these areas are letting heat energy escape from the house.

Infrared image of house indicating areas of heat loss (red and yellow areas)
(Image reference: http://s3.amazonaws.com/digitaltrends-uploads-prod/2014/01/thermal-view-house.jpg)

Efficient Lighting

Incandescent light bulbs work by passing an electric current through a thin metal filament inside the bulb so that it becomes extremely hot and produces light. The light is emitted across a wide range of the electromagnetic spectrum (see figure below) including those that we cannot detect with our eyes, e.g. ultraviolet and infrared light. In fact, only 10% of the input energy is emitted as visible light, the remaining 90% is 'wasted' in other portions of the electromagnetic spectrum or goes into heating the bulb. As a result, incandescent light bulbs are considered energy inefficient.

Compact fluorescent lightbulbs (CFLs) work in a completely different manner than incandescent bulbs: they consist of a spiral-shaped tube that contains argon and mercury vapour. When an electric current, produced by an integrated ballast, passes through this tube the gas molecules become excited and ultraviolet light is generated. This UV light in turns excites a fluorescent coating of phosphor, which lines the inside of the tube, and subsequently causes the bulb to emit visible light. In contrast to incandescent light bulbs, CFLs emit at very specific frequencies and there is only a little light created that is not in the visible spectrum, therefore they are much more energy efficient than incandescent bulbs.



Incandescent lightbulbs have a continuous spectrum (right hand image) and contain all of the visible colours, whereas CFL lightbulbs only emit at specific wavelengths (left hand image)
(Image reference: http://robsacks.com/art/bulb-spectrum-compare.jpg)

It is becoming more common for countries to phase out the use of incandescent light bulbs in favour of CFLs. This change does not come about cheaply however, as CFLs are generally more expensive to produce, but their increased efficiency and longer life-span means that the higher purchase cost is offset in the long term.

Energy Efficiency: Invisible Light Activity Student Worksheet

During this session you will learn about invisible light and energy efficiency by watching a range of demonstrations involving different light sources, and also making and using a spectroscope.

A spectroscope is an instrument that will allow you to observe and analyse various light sources and determine what colours, or wavelengths, of light they contain. When making the spectroscope, you will be provided with a piece of plastic called spectral film that has been produced specially to split light. You will have seen white light from the sun being split into a spectrum of colours by observing rainbows. In a rainbow, drops of water cause different wavelengths of light to be refracted, or bent, differently causing the component colours to be observed separately rather than mixed in white light. The same effect is produced by glass prisms and can also be produced by thin films such as oil on water or the thin ridges of a compact disc.

Procedure

Your teacher will have set up various investigation stations around the darkened room. You will need to move when instructed between the stations to investigate visible and invisible light using your spectroscope and also the other instruments provided. Some activities will be demonstrated to you, but others will investigate yourself.

Ultraviolet and Infrared light

- Your teacher will darken the room and turn on an infrared torch – are you able to see light from it?
- Now your teacher will switch on a modified webcam that allows you to visualise infrared light, what do you observe with the infrared torch now?
- Your teacher will turn on an IR torch and a UV lamp and let you visualise them through the IR webcam. What observations do you make?
- Put the bottle of cola in front of the IR camera – what do you observe?
- Put the banknote in front of the camera and look at the Queen's face – what do you observe? Try to explain your observation **Note to Uniscience: this section may need to be modified/removed, depending on whether local currency works for the activity**
- Use the UV lamp to view a banknote and also fluorescent marker pens. What do you observe?

Spectroscopes

- Assemble your spectroscope, scoring carefully along the indicated lines and sticking the flaps on the **OUTSIDE** of the device to keep the inside as dark as possible. The spectral film goes over the circular hole and you may need to rotate it 90° to view the spectra properly.

NEVER POINT YOUR SPECTROSCORE AT THE SUN!!

- Your teacher will turn on two lamps: one will use an incandescent bulb and the other a compact fluorescent light (CFL) bulb. Note the brightness of the two bulbs. Are they similar or different?

- Point the completed spectroscopes at the two lamps and note the differences between them when using the spectroscope

- Try photographing the spectra by putting a camera to the eye-hole of the spectroscope. Make a note of the similarities and differences you observe

- Point the infrared web cam at both lamps – is there any difference in brightness?

Fluorescent light

- You will be shown a demonstration involving a plasma ball and a fluorescent light, where your teacher will switch the plasma ball on and bring a CFL close to it.
    - What do you observe?
    - What do you think is happening?
    - What does this mean about energy consumption of CFLs?

- Investigate the light produced by the glow sticks

Presentations

You have now seen a number of demonstrations and conducted several investigations linked to energy consumption and light sources. You have also seen some of the uses that can be made of “invisible” light in the UV and IR parts of the spectrum.

Make a presentation, either poster or oral, of your results and what you have learnt in this session. Think about the advantages and disadvantages associated with the results of the activities.

Risk Assessment

LEAD PRESENTER'S DETAILS		
Name:	**Company**:	**Position**:

LEADER'S BIOGRAPHY

ACTIVITY TITLE
Energy Efficiency

SUMMARY OF ACTIVITY
This activity combines a series of investigations and demonstrations that introduces students to the electromagnetic spectrum, and also highlights how energy can be wasted in unseen ways. Practical sessions will involve using different light sources to visualise ultraviolet and infrared light, making spectroscopes to compare incandescent and fluorescent lightbulbs, and studying fluorescent light. The session culminates with students demonstrating the knowledge they have gained via presentations in various formats.

DETAILS OF THE ACTIVITY	
Location of Event:	Date of Event:
Age/Year Group of Audience:	

HAZARD SUMMARY (Each identified hazard must then be detailed below)					
Moving machinery		Public areas		Genetically-modified Micro-organisms	
Lifting, carrying or pulling		Explosions or implosions		Non-GM biological agents	
Sharps	x	Noise		Live Animals	
Electrical	x	Extreme hot or cold items	x	Laboratory animal allergens	

Working at height		Pressure / Steam		Flammable substances	
Falling objects		Naked flames		Chemicals hazardous to health	
Environmental factors (terrain, water, weather)		Cryogenic liquids		Emotive or security issues	
Slips, trips or falls	x	Compressed gasses		Ionising Radiation	
Traffic		Travel		UV / lasers/microwave/other non-ionising radiations	x
Other					

Brief description of the hazardous aspect of the activity	Precautions	Emergency Actions	Is risk high, medium or low?
Sharps: Students use scissors to cut out spectroscope templates. A risk of cutting themselves if not handled correctly	Students are supervised at all times when using scissors Students instructed on how to use the equipment properly	A trained member of staff will give basic first aid. In case of an emergency staff will be made aware of situation and emergency services requested	Low
Sharps: Some fragile glass equipment is used - sharps risk if broken.	Equipment put away immediately after use Students should not be permitted to handle glass bulbs. This should be done by a member of staff Any broken or cracked glass should immediately be disposed of	A trained member of staff will give basic first aid. In case of an emergency staff will be made aware of situation and emergency services requested	Low
Electrical: Desk lamps are used in the session. Electrical risk if bulb were removed from lamp	Leaders will leave a bulb in each lamp at all times. Students not allowed to touch lamps	A trained member of staff will give basic first aid. In case of an emergency staff will be made aware of situation and emergency services requested	Low
Slips, trips or falls: students will be moving around the lab during practical activity	All bags and coats to be stored responsibly to avoid a trip hazard. Students informed to move around room safely	A trained member of staff will give basic first aid. In case of an emergency staff will be made aware of situation and emergency services requested	Low

Extreme hot or cold: Desk lamps are used in the session. Bulbs will get hot - risk of burns if touched	Students briefed on risks, and not allowed to touch lamps.	A trained member of staff will give basic first aid. In case of burns, the affected area should be held under cold running water for at least 10 minutes In case of an emergency staff will be made aware of situation and emergency services requested	Low
UV light: Handheld UV lights will be used. May cause damage to students eyes if shone directly into eyes	Students will be warned of safety issues and informed not to shine the UV lights into student's eyes.	A trained member of staff will give basic first aid. In case of an emergency staff will be made aware of situation and emergency services requested	Low

WHO MIGHT BE HARMED AND HOW?	
Presenter Only:	Audience Plus Presenter: Yes
Support Staff: Yes	Other:

DESCRIBE THE WASTE DISPOSAL ROUTES FOR ANY HAZARDOUS ITEMS
Any broken glass should be disposed of in a sharps bin

SIGN OFF BY HEALTH & SAFETY OFFICER		
Name of Safety Officer:	**Signature**:	**Date**: