TOPIC EXPLORATION PACK

PROVISIONAL

Theme: EM Waves

June 2015

GCSE (9–1) Twenty First Century Physics B

OCR
Oxford Cambridge and RSA

We will inform centres about any changes to the specification. We will also publish changes on our website. The latest version of our specification will always be the one on our website (www.ocr.org.uk) and this may differ from printed versions.

Oxford Cambridge and RSA Examinations is a Company Limited by Guarantee. Registered in England. Registered company number 3484466.

Registered office: 1 Hills Road
Cambridge
CB1 2EU

OCR is an exempt charity.

Contents

This Topic Exploration Pack should accompany the OCR resource ‘EM Waves’ learner activities, which you can download from the OCR website.

This activity offers an opportunity for English skills development.

Introduction

The topic of the EM spectrum can be rather a difficult one for learners to grasp. Many fail to appreciate that the different regions are essentially the same as visible light, albeit with the waves having different frequencies and hence wavelength. It is essential that before commencing with this topic that learners have encountered the ‘anatomy’ of a transverse wave, so that they are familiar with the basic terms of wavelength and frequency before commencing the topic. The first activity does review this idea and stress the link between the two ideas.

The intention of the first activity/demonstration is to illustrate the concepts of a rather abstract idea (the Electromagnetic Spectrum) with an idea that learners will be much more familiar with – that of a musical scale. A keyboard is the obvious instrument to use but in principal others could be used instead. The link between wavelength, frequency and the ‘regions’ of the spectrum is one that learners often have difficulty in making.

A further common misconception is that learners can fail to appreciate that within each region of the spectrum, there are a range of wavelengths and that each region is not monochromatic. A prime example is in categorising the region of the spectrum used for mobile phone transmission which, depending upon the source, states that mobile phones use either microwave or radio waves.

The second activity is to reinforce the major difference between sound waves and EM waves (this follows nicely from the musical EM wave analogy activity). The common misconceptions addressed here are that all waves need something (matter) to propagate through and that light waves can transfer energy from one place to another.

In the third activity, the different regions are introduced with information about each region. The key concept to stress here is that the wave will interact differently with matter depending upon the wavelength (hence frequency and energy) of the wave. The idea that the different sections of the EM spectrum have different uses is usually fairly easily understood as is the concept that different regions have different levels of danger associated with them (depending upon frequency and hence energy).

Activity 1 – Musical Analogy for EM Spectrum

Learning Outcomes

P1.1.1 - describe the main groupings of the electromagnetic spectrum – radio, microwave, infrared, visible (red to violet), ultraviolet, X-rays and gamma rays, that these range from long to short wavelengths, from low to high frequencies, and from low to high energies (part P5.1c).

P1.1.2 - recall that our eyes can only detect a very limited range of frequencies in the electromagnetic spectrum (part P5.1c).

Set up and Necessary Equipment

- A musical keyboard (borrowed from music dept?).
- Post it notes (or similar) to act as labels for the regions of the EM spectrum.
- A way to visualise the wavelength of the soundwave (a microphone connected to an oscilloscope, or better, because it is more straightforward to project onto a screen for the whole class to see is a computer with microphone running the free audacity software (http://audacity.sourceforge.net)). Laptops usually have built in microphones and are ideal.
- A more impressive demonstration is to connect the output of the keyboard to a vibration generator connected to a length of elastic string. When a suitable musical note is played, a standing wave will be produced on the string, the wavelength of which will be immediately visible. (To achieve the standing wave on the string, one may have to vary the note by a key or two until the resonant conditions of the system have been achieved). A string about 2m long works nicely for the frequencies encountered.

The series of pictures shows the wavelength decreasing as the frequency increases.

- An alternative very impressive demonstration is to connect the output of the keyboard to a Rubens tube if one is available.

What to do

Begin by playing a few notes in the middle of the musical range (middle of the keyboard). These correspond to the visible part of the spectrum. Stress that the visible part is only a very small part of the overall EM spectrum.

This video also makes this point nicely http://www.youtube.com/watch?v=kfS5Qn0wn2o

The frequency of the wave is the audible pitch of the note and the wavelength will be visible from one of the approaches used above. Place a post it note with a visible region on the notes played.

Move to a low note, stress how the frequency and wavelength have changed. Add label for Radio region. Continue through the (musical) notes moving towards higher frequencies adding labels to illustrate the order of waves in the EM spectrum. Stress that the boundary between the different regions of the EM spectrum is rather arbitrary and something of a grey area.

As one moves towards the high notes, the frequency increases and the pitch of the waves becomes more 'piercing'. The increasing 'piercing' nature is a useful analogy for the increased energy that the waves possess at higher frequencies, that learners tend to find memorable. The ionising (Gamma, X-ray and Ultraviolet) and non-ionising (Visible, IR, Microwave and Radio) regions of the spectrum should be highlighted.

Extension: discuss the quantised nature of light, Planck's constant and the equation for the energy of a photon of light (E=hf). Direct interested learners to research and investigate the Photoelectric effect.

Extension: (If a vibrating string has been used). The apparatus has only certain waves that form (when the resonant conditions have been met) that are analogous to the allowed energy levels in the atom. An interesting line of questioning to pursue is to ask what the structure of the atom is (the solar system model usually results i.e. with a central nucleus surrounded by orbiting electrons), then elucidate the charge on an electron (negative), then the charge of the nucleus (positive), remind learners of the law of electrostatics (opposites attract) and then ask why don't the electrons simply collapse into the nucleus? The pause that results in learners' responses is usually very warming.

Learner misconceptions to avoid

While there are many similarities, the differences should be stressed. Principally that sound waves are; longitudinal, require a medium to propagate through and travel rather slowly at around 330ms^{-1} while light waves are transverse, require no medium to pass through, and travel at the speed of light (~3 x10^{8} ms^{-1}).

Suggested Plenary

Learners to devise a pneumonic to remember the order of the electromagnetic spectrum.
The pneumonic should then be illustrated with a picture. One example is:

Radioactive	Radio
Mice	Microwave
Invade	Infrared
Venus	Visible
Using	Ultraviolet
X-ray	X-ray
Guns	Gamma

Activity 2 – Transmission of EM Waves

Learning Outcomes

P1.1.3 - recall that all electromagnetic radiation is transmitted through space with the same very high (but finite) speed (part P5.1b).

P1.1.4 - explain, with examples, that electromagnetic radiation transfers energy from source to absorber (part 5.1b).

Set up and Necessary Equipment

- Bell jar, Bell or Buzzer, Vacuum pump
- Crookes Radiometer. If the apparatus isn't available then youtube clips eg http://www.youtube.com/watch?v=sF4MDoIbgcs or http://www.youtube.com/watch?v=RYY7GaPIcUE will suffice.
- Light to illuminate the radiometer. (50W bulb, Bunsen, Candle (will work if placed fairly close in a darkened room), laser pointer pen)

Possible curriculum Link to heat radiation

- IR heat lamps, 4 different materials (squares about 10cm by 10cm of; matt black card, white matt card, shiny foil, foil painted matt black one side). NB: ensure appropriate risk assessment has been completed before attempting this class experiment.

What to do

With the buzzer sounding inside the jar, the sound can be heard outside as the sound vibrations are carried by the air molecules inside to the glass wall then through the air of the room into learner's ears. When the air is removed from the bell jar, the sound is no longer audible but the buzzer is still visible thus demonstrating that unlike sound, light needs no matter through which to propagate.

Show learners the Crookes radiometer, ideally arranged so that it is not rotating then illuminate it with a bright light source (a 50W bulb is ideal). The fins will begin to rotate. Encourage learners to offer suggestions as to how the effect is occurring and discuss and alter variables to investigate the effects (discuss extent to which there is a vacuum in glass bulb, different colour of the each side of the fin (matt black vs shiny silver)).

Possible Curriculum link experiment: Learners should hold their bare forearm about 60cm from the lamp and ‘appreciate’ how warm it feels. Place one of the squares of card onto the forearm and compare and contrast the feeling with the bare forearm. When the black surfaces face the light source, more energy is absorbed and the feeling is noticeably warmer.

The rotation of the fins is clear evidence that the light is transferring some energy to the fins. Thus demonstrating that light (EM waves) can carry energy.

A further useful discussion that could be had is in discussing how energy arrives to the Earth from the Sun. The Sun, of course, providing the source of energy for life on Earth and this energy is transferred through space where there are no particles.

Learner Misconceptions

There remains some debate about the exact mechanism of operation of the Crookes radiometer.

See, for example;
http://en.wikipedia.org/wiki/Crookes_radiometer or
http://math.ucr.edu/home/baez/physics/General/LightMill/light-mill.html
for useful background information.

One remains on safe ground here if one limits the discussion to the indisputable idea that the light transfers some *energy* to the fins of the radiometer.

Extension: An excellent stretch and challenge activity for the interested learner would be to fully research and investigate the scientific theory to explain how the radiometer works. Playing devils advocate to oppose whatever idea the learner concludes will really stretch their understanding and ability to form evidence based conclusions. The task is particularly useful to illustrate the idea of discussion and debate within the scientific community, as there is such a wide range of material and opinions on the web.

Activity 3 – EM Circus Activities

Learning Outcomes

P1.2.1 - recall that different substances may absorb, transmit, or reflect electromagnetic radiation in ways that depend on wavelength (part P5.2a).

P1.2.3 - recall that changes in atoms and nuclei can generate and absorb radiations over a wide frequency range (P5.2c):

a) gamma rays are emitted from the nuclei of atoms
b) X-rays, ultraviolet and visible light are generated when electrons in atoms lose energy
c) high energy ultraviolet, gamma rays and X-rays have enough energy to cause ionisation when absorbed by some atoms.

P1.2.4 - describe how ultra-violet, X-rays and gamma rays can have hazardous effects, notably on human bodily tissues (part P5.2d).

P1.2.5 - give examples of some practical uses of electromagnetic radiation in the radio, microwave, infrared, visible, ultraviolet, X-ray and gamma ray regions of the spectrum (part P5.2d).

P1.2.6 - recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits (P5.2b).

Set up and Necessary Equipment

- Blank template (EM Circus Blank). For students to fill in as notes when completing the circus.
- EM Circus experiment sheets for students. (Circus Question Sheets). There is also a sheet for teachers and technicians with expected answers.

What to do

Learners then move round between the stations completing any experiment at that station and gathering the key information about that station's region of the EM spectrum.

Radio

Set up and Equipment	What to do	Notes and comments
An appropriate picture to send via Bluetooth eg the Bluetooth symbol Materials to test the transmission of Bluetooth signals through • Paper • Card • Sealed plastic bag • Wooden blocks (arranged in an enclosing structure) • Water (a do-nut shaped container with a water container above and below) • Metal enclosure eg a biscuit tin or pencil case	Using their own mobile phones, learners take a picture of the image provided and then send it to one another. Experiments • to find the maximum range of transmission • whether the signals rely on line of sight • whether the signals can be transmitted through different materials	Learners should find the range is about 12-15m. Learners should be encouraged to make a prediction, with a detailed scientific reason before attempting the experiments. Despite what one might expect, I have found empirically that the metal enclosure will only block the signal if it is correctly Earthed.

The suggested experiment here is to use the Bluetooth function present on mobile phones that uses radio waves (wavelength of about 12.5 cm and a frequency of 2.4 GHz) to communicate with other electronic devices.

If higher tier learners, the discussion information provided should describe how radio waves are produced by oscillating electric fields in a conductor (i.e. the antennae of the devices).

Microwave

Set up and Equipment	What to do	Notes and comments
Laptop with access to web address below.	Play the video clip describing how glass can be made to melt inside a standard microwave oven. Learners to write a paragraph explaining the experiment.	The brave teacher will attempt this demonstration in the classroom. I haven't managed to get it to work in trials, however. Presumably there is a specific sort of glass that works well.

Bang goes theory film clip:
http://www.bbc.co.uk/schools/teachers/bang/videos/lesson15_electromagnetic_spectrum.shtml

InfraRed

Set up and Equipment	What to do	Notes and comments
Remote control Digital Camera	The IR output from a remote control can be visualised by pointing the remote control into a digital camera. It works best when set to video mode.	
IR detector* IR LED source* Plane mirrors 45^{o} Prisms	The IR LED source can be used to demonstrate that IR light behaves as visible light and obeys law of reflection etc.	Possible additional experiment - Connect IR detector to a multi-meter recording voltage (mV) for an intensity vs distance experiment.
	Directing the output from the remote control into the IR detector makes it flash and illustrates that the devices use a coded digital signal.	The flashing effect cannot usually be observed with a digital camera.

*A risk assessment should be performed before using these devices as the IR light could cause eye damage if inappropriately used.

Visible

Set up and Equipment	What to do	Notes and comments
Computer projector Polaroid sheets	Arrange the projector to display a white image. Place a polaroid filter between the projector and the screen. The white screen will appear to be coloured. Rotate the filter by 90^o, the colour of the coloured region will change. Insert a second polaroid filter and rotate until it's plane of polarisation is at 90^o to the first. The colour of the region will change again.	This experiment illustrates that white light displayed in this way is made up of red green and blue components. Each colour of light from the projector is polarised in a different way and the polaroid filters remove the different coloured components individually leaving the opposite corresponding colour on the display.
Laptop computer Magnifying Glass	Use the magnifying glass to view a laptop (or tablet) screen. The individual red, green and blue pixels are visible.	

The link below gives an introduction to the theory of the use of red, green and blue components to make images:
http://en.wikipedia.org/wiki/RGB_color_model

UltraViolet
In addition to the standard UV demonstration apparatus (Commercial UV light, Highlighter Pens, Bank Notes, Tonic Water (containing quinine), suntan lotion etc) further experiments can be performed with low cost UV LED light sources as described for the IR section. The UV light can be readily viewed with fluorescent paper available on the high street.

X-ray
Display images of X-rays. Hospital radiology departments are often very amenable to providing 'real life' films if requested for teaching purposes. Some will even provide a description of the injury shown by the film. Learners could then attempt to diagnose the problem from the X-ray image.

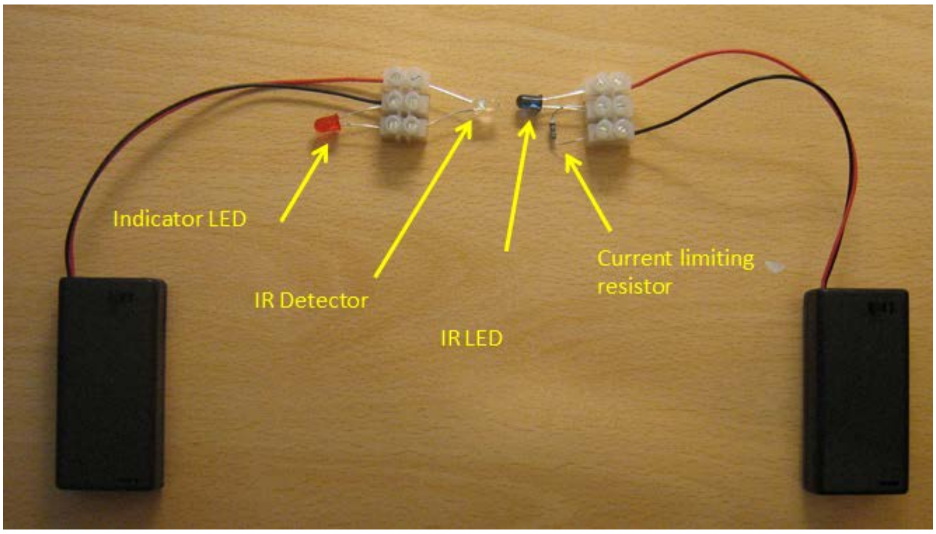
Gamma

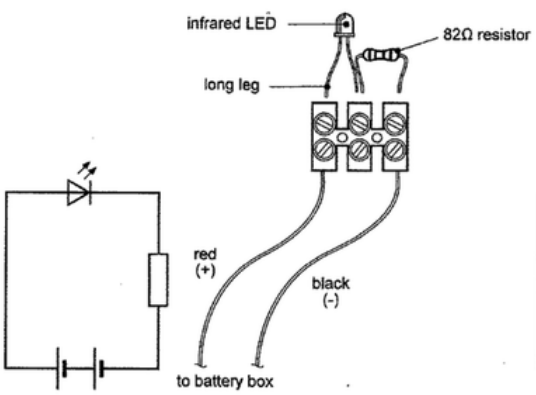
http://www.insidestory.iop.org/insidestory_flash1.html

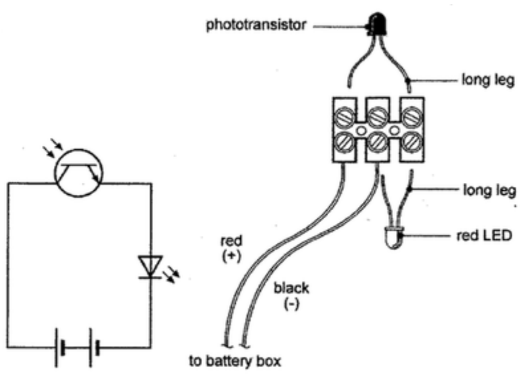
This is an excellent flash game. If IT equipment is available, learners could complete this individually and then write up their findings in a medical record type format, noting down doses and angles used, together with 'damage' caused to the tumor and also the surrounding tissues etc. Showing the game on the board and choosing individual learners to be 'Radiographers' could lead to a competition as to who is the most successful. This links very nicely to P1.1.4 and P1.2.4.

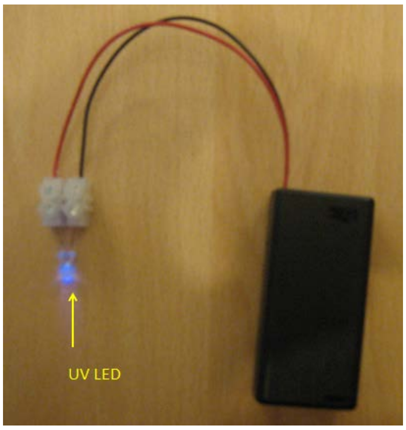
Appendix

Making the IR / UV light Sources









List of Components with Rapid Electronics part numbers – other suppliers are available!

Description	Rapid Part Number (cost)
2 AA battery box and switch	18-2906 (0.38)
Terminal Blocks	21-0100 (0.88)
IR LED Source	58-0320 (0.22)
IR Detector (Phototransistor)	58-0325 (0.20)
1.2K resistor pk 100	62-2102 (1.63)
Red LED	56-0430 (0.07)
UV LED	55-1835 (0.68)

ocr.org.uk/gcsereform

OCR customer contact centre

General qualifications

Telephone 01223 553998
Facsimile 01223 552627
Email general.qualifications@ocr.org.uk

A DIVISION OF CAMBRIDGE ASSESSMENT

LLOYD'S REGISTER · LRQA ISO 9001

UKAS MANAGEMENT SYSTEMS 001