UCL

The Scholars Programme

METABOLIGHT

Illuminating the Body

Key Stage 3 Programme

Integrated Engineering Programme

Pupil Name		Tutorial Group	
PhD Tutor			

THE SCHOLARS PROGRAMME S THE SCHOLARS PROGRAMME

BROUGHT TO YOU BY B THE BRILLIANT CLUB

Course Rationale

This course will teach students about the engineering design process through the design of a medical physics device. Students will learn how physics can be applied to medicine, how engineers use physical principles to design machines and how scientists interpret data. The course focusses on near-infrared spectroscopy which is a technique that uses light to measure changes in blood flow in the brain. Learning about this technique will introduce them to new physics ideas, building upon those they already understand, and then apply them to new situations.

The course begins with an introduction to the engineering design process. The second tutorial looks at the concepts of how we could design a near-infrared spectroscopy system from the perspective of physicists, who are interested in how light interacts with the body and how we can exploit this to measure the inner workings of the body. Tutorial three will showcase a research project, MetaboLight, which uses NIRS to monitor metabolism in the brains of babies. The fourth tutorial will look at the engineering behind a NIRS machine: how each component works (e.g. optical fibres, LEDs, spectrometers), and how engineers make the system work for the application (e.g. is it safe to put on a living person?). In this tutorial the students will start to think about how they could design a NIRS system for a different application: monitoring muscle in athletes.

The tutorials will conclude with the final assignment which brings everything together. The students will write a 1500-word report showing the design of a NIRS system to monitor muscle on athletes.

Front cover image: Engineering light to monitor brain health in babies https://metabolight.org/

Sample Tutorial Activity

Objective 1: To know that white light is made up of all colours

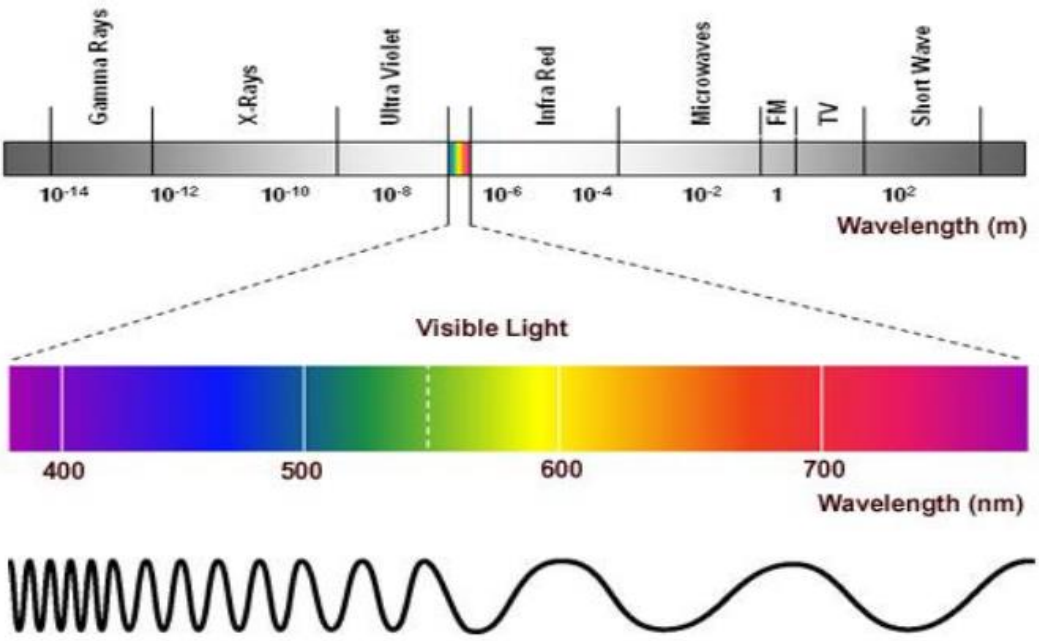


Image from: https://aquanswers.com/led-lights-for-aquarium-plant-growth-best-color/

Shine a white light (torch) into a prism or diffraction grating. What do you see? Draw it below with labels.

Why does this happen?

Near-infrared light ranges from 600nm to 1000nm, label this on the spectrum above.

Objective 2: To understand how light interacts with the body

UCL, Image from: https://www.bbc.co.uk/news/health-45522794

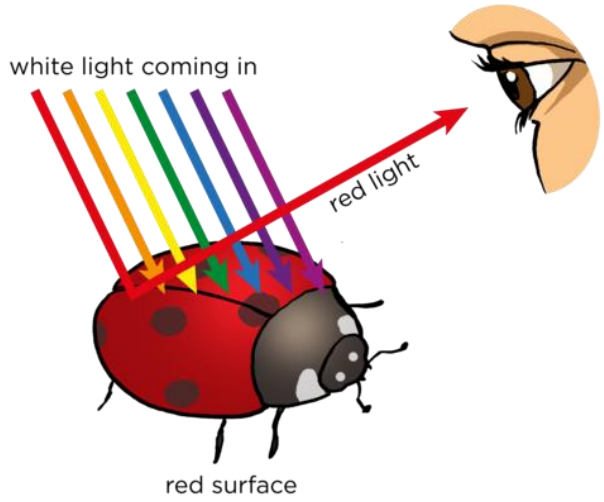
Shine a torch through your hand. What can you see? Why?

What can you *not* see? Why?

How can medical engineers use this effect to measure your pulse rate?

Objective 3: To find out about colours inside the body

When light reaches an object, some of the light is absorbed and some of it is reflected. This is how we see colour. The light that is reflected is the colour we perceive the object to be.



Why do we see <u>black</u> dots on the ladybird?

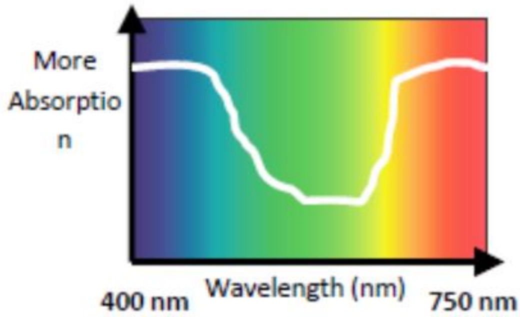
Spectroscopy is the process of measuring the spectrum unique to an object or molecule. Optical spectroscopy shines white light onto things and measures the spectrum that is reflected back. You do this with your eyes all the time! If you don't have white light, you can use different colours and see how much of each an object reflects to tell which colour it is.

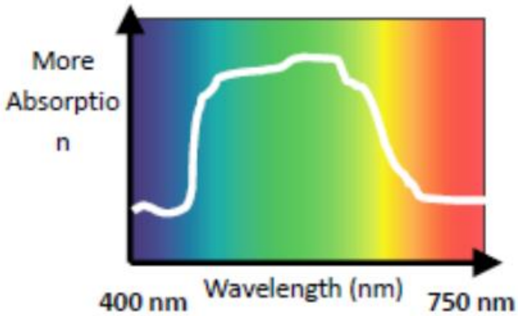
Task: Turn the lights off and use two different coloured LED lights to identify the colours of 3 gummy bears (without white light!) – how can you do this?

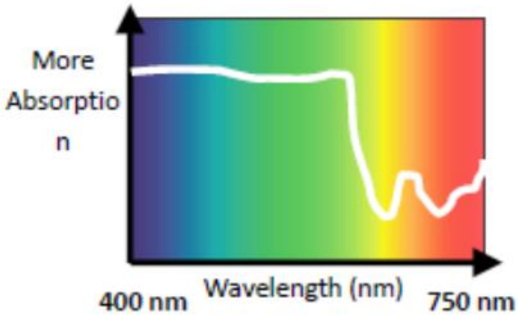
Image from: https://pixy.org/127279/

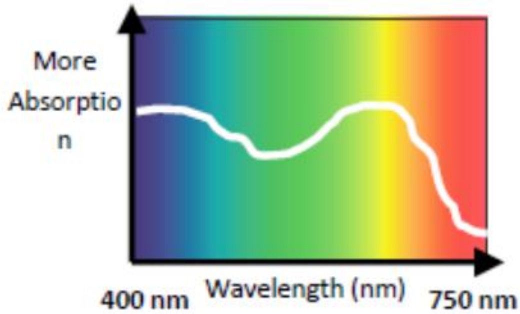
An absorption spectrum shows the colours of light (wavelengths) that are absorbed by an object.

Task: Match the absorption spectra to the objects below:

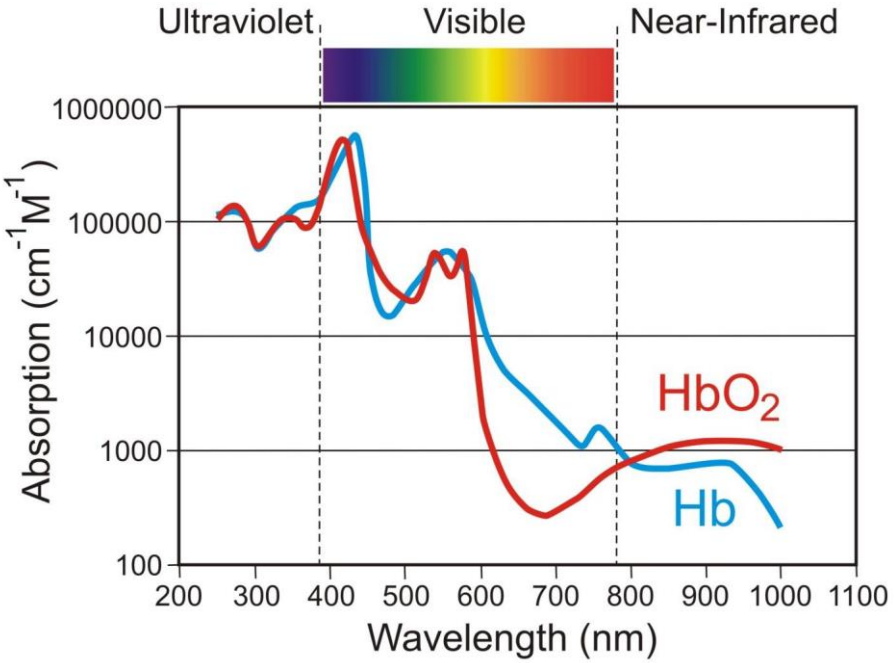








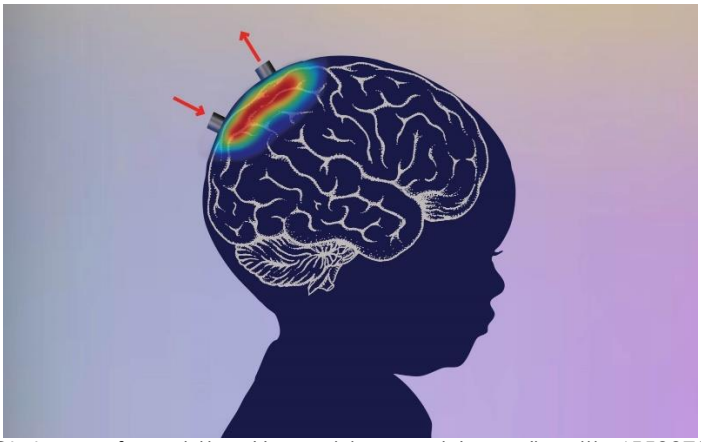
We saw that when we shone white light into your hand, red light was transmitted. If we measured the spectrum of the light transmitted it would look like the graph below. Note that there are two lines, one for blood when it is bound to oxygen (oxygenated haemoglobin, HbO_2) and one for blood when it is not bound to oxygen (deoxyhaemoglobin, Hb).



This means that the blood is a different colour depending on how much oxygen is in it. What colour will purely oxygenated blood be, compared to deoxygenated blood? Label the two types of blood below:

Look at the blood spectra again, which kind of light (ultraviolet, visible or near-infrared) do you think is more suitable for imaging the brain? Why? Discuss this with the group and consider what we need to get light into the head and get it out again.

Objective 4: To understand how near-infrared spectroscopy works



UCL, Image from: https://www.bbc.co.uk/news/health-45522794

We have learnt that near-infrared light can travel through the body and will be absorbed by different molecules within the body. We also know that the molecules in the body have specific colours or spectra. This means that by measuring the absorption spectra coming out of the body, we can find out which molecules are inside the body and how much of them there is. This is called near-infrared spectroscopy and is used by medical engineers and doctors to monitor how much oxygenated and deoxygenated blood there is in the brain.

Watch the video below to see a NIRS research team in action:

www.metabolight.org/#film

The team measure metabolism – what is metabolism?

How do the team measure metabolism as well as blood oxygenation?