

# SSERC *Bulletin*



Ideas and inspiration supporting science and technology for all Local Authorities

No. 251 - Summer 2015

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# Equipment for local authorities

Once again, SSERC has been able to source 3 substantial pieces of scientific equipment to give out to local authorities on a permanent loan.

Item one is a box of four Mystrica colorimeters (Figure 1). Colorimetry is a valuable analytical technique in many areas of biology and chemistry. Though of most use from National 4/5 and above, colorimetry can be used at any age group. The machines are robust and easy to use and can be connected to PCs, iPhones and iPads to allow much easier use for looking at, say, rates of reaction.

Item two is for use with last year's provision of a spectrophotometer/datalogger. It is a fibre-optic probe for the spectrophotometer that allows analysis of emitted radiation, such as light sources or flame colours, in addition to the analysis of absorption of solutions the apparatus currently allows. This probe extends the usability of the device into more areas of chemistry, Advanced Higher in particular, and into physics.



Figure 2 - Tracks in a cloud chamber.



Figure 1 - Mystrica colorimeter.

The third item (Figure 2) is a cloud chamber. Radioactivity is part of both the chemistry and physics Senior Phase courses. Particle

Physics has been introduced at Higher and Advanced Higher. One piece of equipment that really engages learners with these topics is the cloud chamber. Invented by Scottish Nobel Prize-winning physicist CTR Wilson, this beautiful apparatus shows tracks left by radiation and cosmic rays as vapour trails. Traditionally, cloud chambers have been tricky to set up, with most requiring dry ice. The device we are supplying is electrically cooled. It comes with a piece of mildly radioactive welding rod which requires no special storage or transport provision. Add a small amount of isopropyl alcohol, switch on the chamber in a darkened room and particle tracks appear in minutes.

SSERC will also be providing a copy of Control Studio and Live Wire software to every local authority school. ◀

# Interfacing with Arduino UNO - part 2: output signals

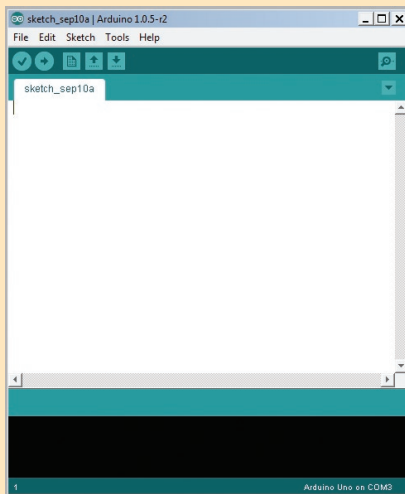


Figure 1 - IDE Screen.

Double click the Arduino icon, select FILE and then NEW. The blank IDE screen is displayed as shown in Figure 1.

A program is called a SKETCH.

## Making comments within a program

At any position in a sketch, comments can be made. Comments are ignored by the microprocessor - they exist purely for human assistance.

## The // comment

is limited to one line, for example:  
`// This program flashes LED's`

Notice, you don't require a second set of '/' at the end of the text. The new line ends the text!

You can program as many '/' comments as you like, for example:

```
// this program flashes LEDs
// Red for stop
// Green for go
```

In a previous issue (SSERC Bulletin (2014), 249, 6-7) we promised an article on interfacing; here it is...

**Note:** Comments are removed during the 'compiling process' and hence never reach the Arduino board.

## The /\* Comment

This allows text to go beyond one line, e.g. long sentences or paragraphs. The /\* indicates the start of the text, and in this case, the end of the text needs to be indicated, so \*/ is the end of text marker. So:

```
/* start of text
*/ end of text
```

Typically, this command could be used to contain the sketch title and a brief description of what the sketch does.

## The semi colon (;)

Because the programming language used in Arduino is based on the C Language, each line of program requires an end marker, in 'C' this marker is the semi colon.

Typical code:  
`delay(1000);`  
`delayWrite(13, LOW);`

**REMEMBER: use the semi colon.**

## Program outline structure

C Programming involves 'Functions' - blocks of code. The structure of an Arduino sketch at the start always involves two functions and is shown in Figure 2. This is a sketch outline taken from the IDE display. The two functions are called 'setup' and 'loop' The system will run through 'setup' once only, while within the 'loop', it continually loops around

the contents of the loop function as shown by the arrows in Figure 2. Setup is the ideal place to declare constants, values etc. (more later). After the setup function is used the program enters the loop function, where it is essentially trapped within a loop, over and over again. Note, the arrows on Figure 2 are there to demonstrate the program direction, they do not exist on the IDE.

This 'loop' function is stopped basically (at this stage) by disconnecting power from the Arduino.

## Curly brackets

Notice the curly brackets (Figure 2), each bracket indicates the start or the end of each function.

**REMEMBER: curly brackets in pairs.**

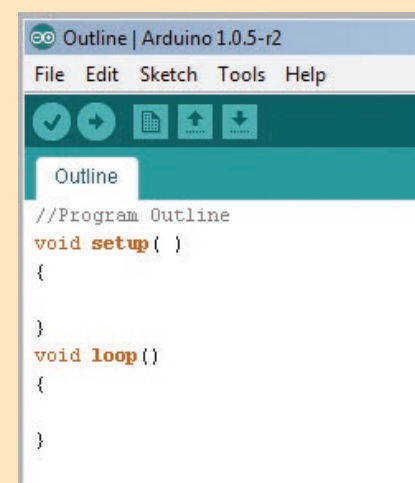


Figure 2 - Program outline.



Figure 3 - Digital connections on the Arduino UNO Board.

### Time delay

The Arduino system works with a millisecond clock. The command 'delay' gives a time delay, but the value of the delay must also be included with each 'delay' command,

Delay(value);  
value must be a number.

For a 1 second delay  
delay(1000);

For half a second delay  
delay(500);

**REMEMBER the semi-colon.**

### Outputting digital signals

Notice in Figure 3 that there are 14 output connectors (pins) on the Arduino UNO board.

(numbered 0 - 13). Before they can be used, they need to be 'set up'.

### pinMode(pin, mode)

pinMode is the code for setting up these digital pins. 'pin' refers to the number of the pin(connector), pin is simply a number between 0 and 13. As these pins can be set to either input or output, the mode command indicates which.

So to set pin 13 for output:  
pinMode(13,OUTPUT);

To set pin 5 for input:  
pinMode(5,INPUT);

The ideal place for these commands would be within the 'set up()' function.

**REMEMBER: you must set the pins up before any attempt to use them!**

**REMEMBER the semi-colon.**

### Using the Pins

Assuming that the pins are set up using the pinMode(pin, mode) command(s) output signals can now be generated from within the loop() function.

The code to trigger an output signal is:

**digitalWrite(pin, value)**

In order to output a signal, the pin number must be known and whether that pin is to be switched HIGH or LOW(value), where HIGH is 5 V, LOW is 0 V.

Typical:

**digitalWrite(13, HIGH);**  
//this would turn pin 13 On (5 V)

**digitalWrite(13, LOW);**  
//this would turn pin 13 Off (0 V)

### TASK 1

Using a blank IDE screen (Figure 1), type an outline sketch structure as shown in Figure 2. Use FILE and SAVE this sketch outline as 'Outline' When the sketch is saved, the name 'Outline' is displayed just above the sketch code. This sketch 'Outline' saves retyping 'setup() and loop()' each time. This gives a template sketch for further use.

### TASK 2

Using digital pin 10, flash a LED connected to this pin, on for 0.5 seconds, off for 0.5 seconds. This flashing is to be repeated continuously. At this stage write the sketch and save the sketch as 'task 2'.

Notice in Figure 4, within setup() is the setting of pin 10 to a digital output signal. Remember, pins must be 'setup' before using the 'pinMode' command.

```

TASK_2 $
setup ( )
{
  pinMode(10, OUTPUT);
}

loop ( )
{
  digitalWrite(10, HIGH);
  delay(500);
  digitalWrite(10, LOW);
  delay(500);
}

```

Figure 4 - TASK 2 Sketch Code.

Within the loop function (Figure 4), pin 10 is turned on via 'digitalWrite(10, HIGH);

Then a 0.5 second delay...  
**delay(500);**

Then switched off...  
**digitalWrite(10, LOW);**

Then, off for 0.5 second using...  
**delay(500);**

**Note:** this second delay within the loop is often missed out when developing the code, without this delay, due to the loop the 'LOW' signal is immediately followed by the start of the next loop and digitalWrite(5, HIGH) swamps the 'LOW' - the LED will never appear to be LOW!

Give the 'LOW' a chance...  
include its own delay(500);

### Hard wiring an LED to the Arduino UNO Board

Figure 5 shows the connection of an LED. This circuit uses Pin10 switching on or off via a sketch (Figure 4). The circuit is completed via the Arduino GND (ground) connection. When Pin 10 is switched on, 5 V can be measured between GND and Pin 10. This would quickly 'blow' the LED and so a resistor needs to be inserted into the circuit in order to reduce the voltage across the LED. The red wire can of course be connected to any of the digital output pins.

What size of resistor? is a common question. The resistor value depends upon which type of LED is used. Typically a white LED requires 3.2 V voltage drop across the LED, 25 mA. LED current. With Arduino there is a 5 V drop between 'GND' and any 'on' pin.

Websites exist which will calculate resistor values in LED circuits, for example, <http://ledcalc.com/> For the values above, the resistor value is 72 ohms. The website also give the nearest actual resistor value, in this case 82 ohms. The supply voltage for Arduino is 5 V, the voltage drop across the LED and the LED current need to be provided from data sheets for the LED that are being used.

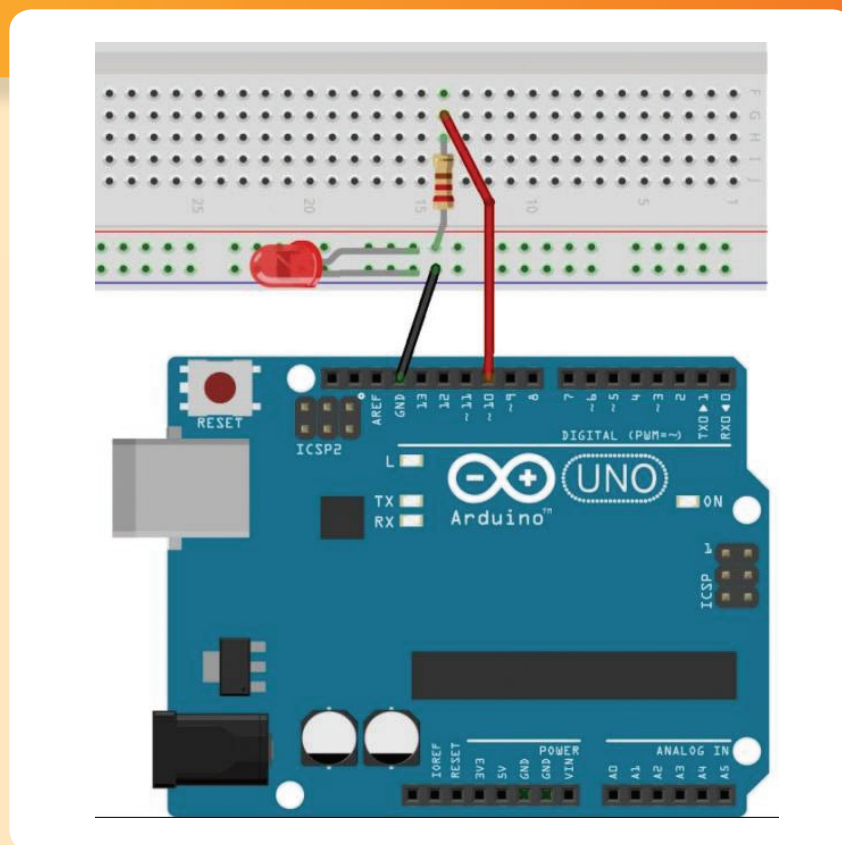


Figure 5 - Connecting an LED to Arduino.

### Calculation of resistor value for an LED circuit

Arduino supply voltage = 5 V, typically LED voltage drop 3.2 V, LED current = 25 mA = 0.025 A

$$\text{Resistor Value} = \frac{\text{Supply Voltage} - \text{LED voltage drop}}{\text{LED current (I)}} = \frac{(5 - 3.2)}{0.025} = 72 \text{ ohms}$$

### TASK 3

The Northern Lighthouse Board has a website [www.nlb.org.uk](http://www.nlb.org.uk). Investigate the Butt of Lewis lighthouse and determine the 'character' of this lighthouse.

'Character' is the pattern of light with corresponding timings. Develop, using Arduino a continuous flashing circuit which mimics the Butt of Lewis lighthouse. Use as a digital output, pin 1.

(Answer: Butt of Lewis Lighthouse: flashing white light every 5 seconds).

### TASK 4

Write code for a set of traffic lights, build using three LEDs a working model.

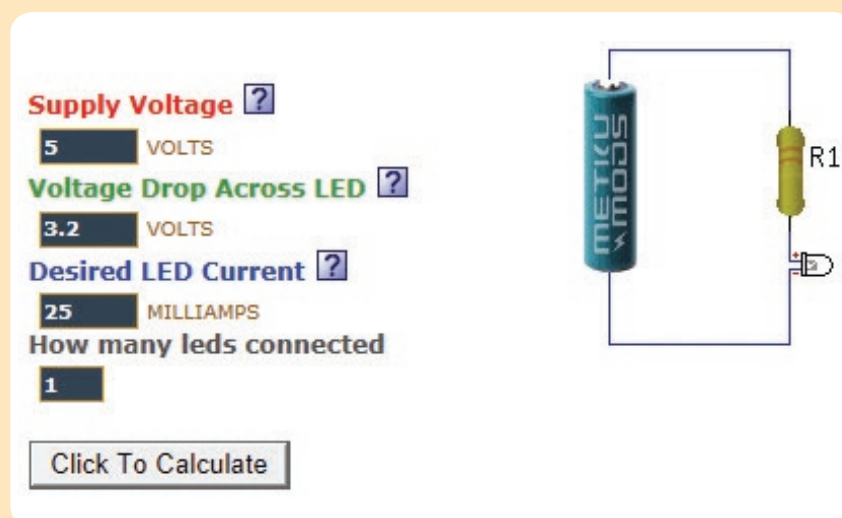


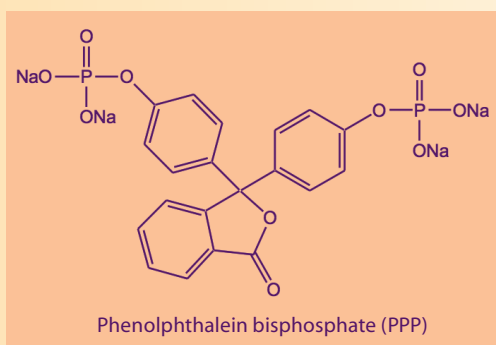
Figure 6 - 'ledcalc.com' Resistor Calculator.

# Fun with Phosphatase

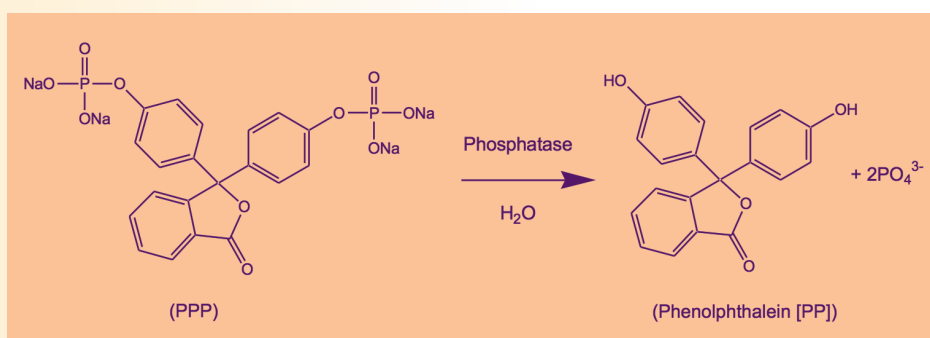
Within SSERC we believe that assays of phosphatase activity are useful in a variety of protocols and some of these are detailed here. The experiments described here are not new and are, in large part, based on the work of Meatyard [4].

Phosphatase enzymes are involved in a range of metabolic reactions. A key function of these enzymes is to release phosphate groups into the metabolic pool thereby increasing their availability for use in a range of processes including ATP synthesis and membrane construction. Acid phosphatases (those with a pH optimum below 7.0) can be extracted from a range of plant tissues with germinating mung beans being a particularly cheap and reliable source (see section marked 'Experimental' for more details).

The substrate used here for phosphatase is phenolphthalein bisphosphate (abbreviated as PPP):



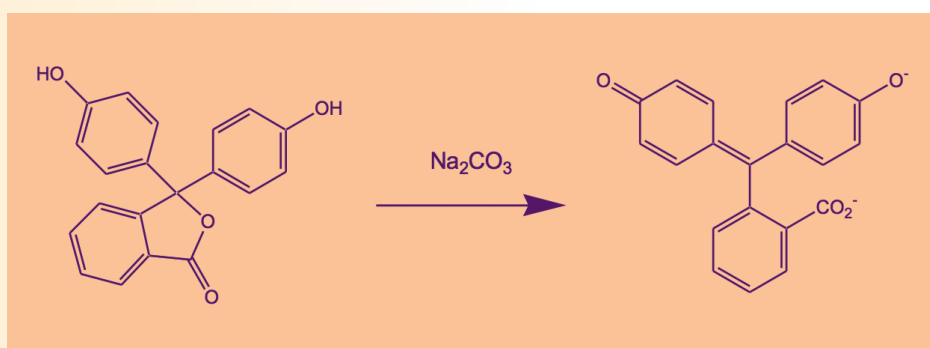
In a previous issue of the SSERC Bulletin [1] we explored how the enzyme dopa oxidase might be used to support learning and teaching across a range of curriculum levels. Phosphatase is one of the enzyme systems specifically mentioned in both of the recently implemented *CfE* Highers in Biology [2] and Human Biology [3]. A particular emphasis is the use of phosphatase in '*experiments on product inhibition*'.



Under suitable conditions the enzyme phosphatase catalyses the following reaction as shown above.

At neutral or acidic pH the products of the above reaction (phenolphthalein [PP] and phosphate) are both colourless and their presence is, therefore, difficult to detect. This can be

overcome through the addition of sodium carbonate which has 2 major effects: (i) raising the pH of the solution to above 10 with consequent cessation of enzyme activity and, (ii) converting (colourless) phenolphthalein to its anionic form with its characteristic pink colour in solution:



A detailed protocol (together with a supporting PowerPoint) for 'a standard assay' is available on the SSERC website (<http://www.sserc.org.uk/index.php/biology-2/biology-resources/higher-biology-revised/metabolism-a-survival/3426-metabolism-is-essential-for-life>) but briefly our preferred assay system can be described as:

- Place 1 cm<sup>3</sup> of the sodium carbonate solution into each of 7 cuvettes.
- Prepare enzyme extract and substrate solutions and store them at a given temperature.
- Mix enzyme extract with buffer of desired pH.
- Add 1 cm<sup>3</sup> of the mixture in (c) above to the first cuvette and use this solution as your blank.
- Add substrate solution to the mixture of enzyme extract and buffer.
- At 1 minute intervals remove 1 cm<sup>3</sup> of the mixture in (e) above and add it to one of the cuvettes containing sodium carbonate solution.
- Measure the absorbance of the solutions at 550 nm.

As can be seen in Figure 1 an increase in the concentration of phenolphthalein is readily observed after a few minutes and changes can be readily observed using a colorimeter.

### Investigations

With a working assay one might think about how this could be incorporated into a student investigation. As noted above phosphatase is inhibited by increased concentrations of phosphate and so is often used as an example of end-product inhibition. Other areas which are worthy of investigation include:

- Effect of temperature.
- Effect of pH.
- Phosphatase levels from different species.
- Phosphatase levels in different locations of the same species.



Figure 1 - Changes in colour observed after 1 minute intervals as described in step (f) above.

In particular Meatyard [4] highlights the pH and temperature profiles of phosphatase extracted from mung beans (shown in Figures 2 and 3) and these are worthy of further exploration.

### Experimental

#### 1 PREPARATION OF ENZYME EXTRACT

##### 1.1 Mung bean germination

Take 2 g of mung bean seed for each group of students and place

in a dark container with a lid (e.g. margarine tub or similar). Make sure that the container is sufficiently large so as to ensure that there is only a single layer of seed. Cover the seed with tap water, replace the lid and leave for 24 h at a temperature of 30°C - this can usefully be achieved by floating the container in a water-bath. After 24 h drain off the water and rinse with fresh tap water. Replace the lid and return to the water-bath. From this time on seeds should be kept moist but

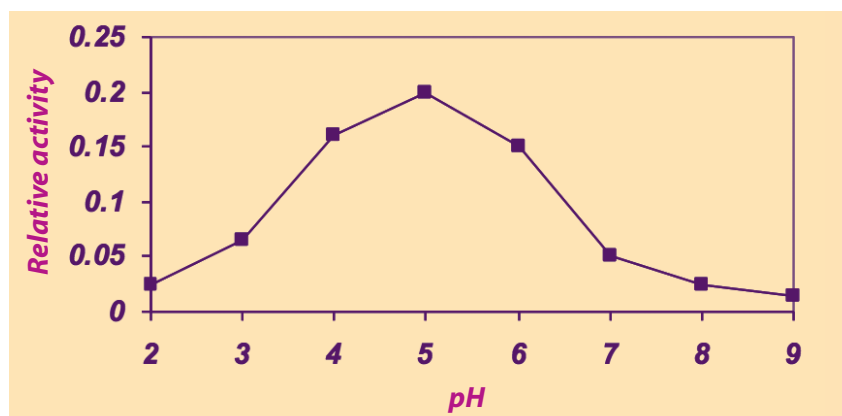


Figure 2 - Effect of pH on activity of phosphatase extracted from mung beans [4].

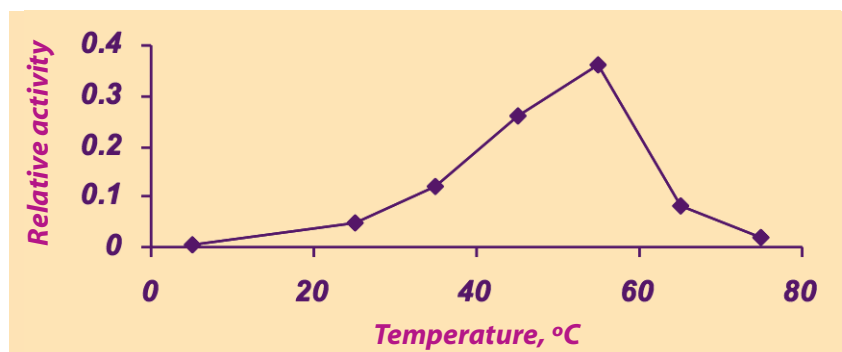


Figure 3 - Effect of temperature on activity of phosphatase extracted from mung beans [4].

not soaking in water. Repeat this rinsing procedure at 48 h and 72 h. The optimal size of seed is reached when the radicle (seed root) has reached a length of 3 - 4 cm.

### 1.2 Extraction of enzyme

Enzyme extracts lose activity over time and it is strongly recommended that enzyme extracts are prepared on the day of use. For each group of students select 12 seedlings (3 - 4 cm in length) and place them into a mortar. If the green testa (seed case) is still attached it is important that it is removed and discarded. Add approximately 5 cm<sup>3</sup> of tap water and grind the seedlings with a pestle until a smooth paste is obtained. Add a further 10 cm<sup>3</sup> of tap water to the paste. The crude extract should be centrifuged for at least 5 min at a minimum of 2500 g. Carefully remove the supernatant and dispense into small bottles.

If you do not have access to a suitable centrifuge, enzyme extracts can be prepared by using 10 cm<sup>3</sup> of water rather than 15 cm<sup>3</sup> of water for each group of 12 seedlings and allowing the extract to settle at 4°C overnight. Carefully remove the supernatant and dispense into small bottles as above.

### 1.3 Extraction of enzyme from bean-sprouts

Many supermarkets offer bean sprouts for sale and these can be used in place of mung beans

Homogenisation of approximately 100 g of bean sprouts (no additional water should be added) should produce approximately 50 cm<sup>3</sup> of crude extract. This crude extract should be filtered through muslin and then centrifuged as above. Carefully remove the supernatant and dispense into small bottles.

### 2 MATERIALS

PPP is available from Sigma-Aldrich (<http://www.sigmaaldrich.com/>) as the tetrasodium salt - catalogue P9875-1G; cost £14.30 g<sup>-1</sup>.

#### References

- [1] Dopa oxidase - a perfect enzyme? SSERC Bulletin, 242, 8-10.
- [2] SQA (2014) Higher Biology Course Support Notes - available at [www.sqa.org.uk/files\\_ccc/CfE\\_CourseUnitSupportNotes\\_Higher\\_Sciences\\_Biology.pdf](http://www.sqa.org.uk/files_ccc/CfE_CourseUnitSupportNotes_Higher_Sciences_Biology.pdf).
- [3] SQA (2014) Higher Human Biology Course Support Notes - available at [www.sqa.org.uk/files\\_ccc/CfE\\_CourseUnitSupportNotes\\_Higher\\_Sciences\\_HumanBiology.pdf](http://www.sqa.org.uk/files_ccc/CfE_CourseUnitSupportNotes_Higher_Sciences_HumanBiology.pdf).
- [4] Meatyard, B (1999), Phosphatase enzymes from plants: a versatile resource for post-16 students. J Biol. Ed., 33, 109-112.

## Year of Light

### EnLightenment: build it, see it, show it

To celebrate the UN International Year of Light 2015, Heriot-Watt University and the Wellcome Trust are launching a smartphone microscope competition for schools and the public!

In collaboration with SSERC, we have developed smartphone microscope kits, which we will be distributing to secondary schools across Scotland. S1 pupils can build the microscopes and take their own images of life in miniature; these images can be entered into a competition to win a prize presented by Prof. Jim Al-Khalili at the Scottish closing event of the International Year. The public will also be able to enter the competition at various science festivals during 2015.



Schools can register their interest at <http://eepurl.com/bhX2uP>

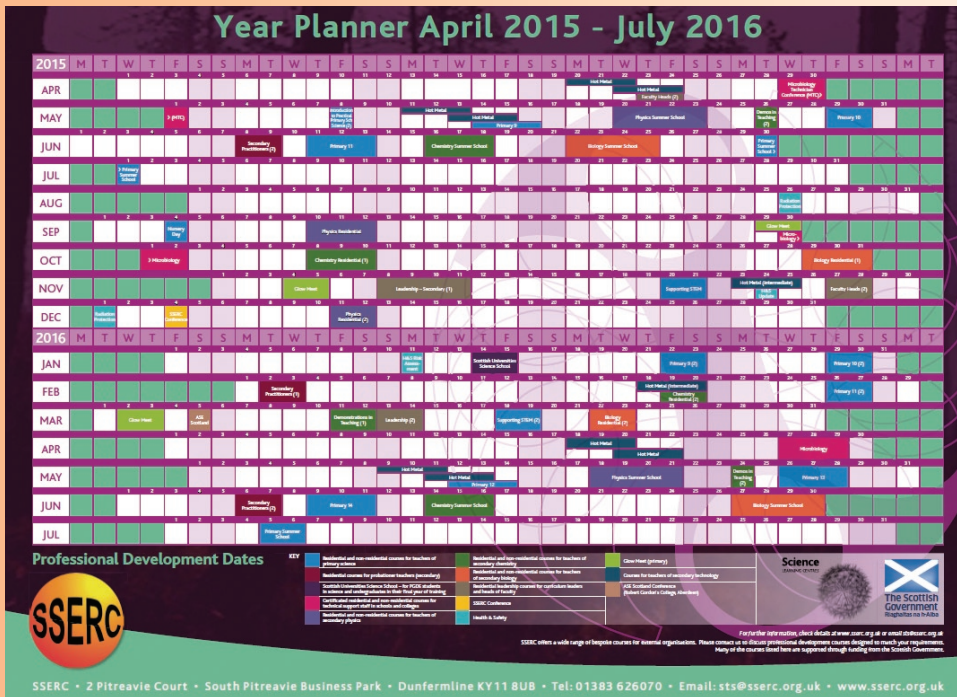


# What's new?

We are delighted to report that SSERC has received an offer of funding from the Scottish Government to support professional development activities across the primary and secondary sectors.

Consequently, and as in previous years, this has allowed us to publish a 'year planner' to the end of June 2016. Copies of the planner have recently been sent to schools throughout Scotland. As we add new courses the planner will be updated and it can be accessed on the SSERC website.

Further copies of the 'year planner' can be requested - email us at [sts@sserc.org.uk](mailto:sts@sserc.org.uk).



## Advanced Higher Design & Manufacture project assessment announced

Details of the new *CfE* course structure have been announced at recent SQA subject implication events and led to changes in the way senior students' work will be completed and assessed. The new qualification will be a 120 mark project (worth 60% of the total marks available). The new project assessment is now also restricted to just 20 A3 pages and will be set, conducted, marked by classroom teachers and then internally verified in presenting schools.

This is a change from the old Advanced Higher Product Design Extended Case Study where there was

no page response limits and it was not uncommon to see student entries contain over 100 A3 pages. Marking was also previously conducted centrally. The second component of course assessment is the traditional exam paper which is now worth 80 marks (40% of the total marks available) and must also be completed in 2 hours. The new Design & Manufacture course is introduced from August 2015.

For more details go to <http://www.sqa.org.uk/sqa/48468.html>.

# Using the Spectral Workbench

In the last Bulletin we showed you how to make a simple spectrometer attachment that will fit onto your mobile phone. This allows you to take pictures of spectra.

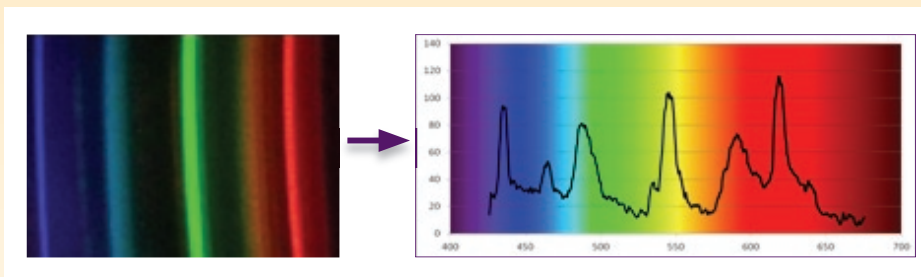


Figure 1

That is all very well but just having a picture of a rainbow-like image is not all that useful. In order to do proper science with it, you need some way of analysing the image to get a graph showing how intensity varies with wavelength.

Some of you physicists might have had some experience using Tracker.jar for this. (A favourite of the SSERC Physics team, it can analyse spectra as well as, more commonly, analyse motion). It is, however, a little fiddly to use.

Recently, however, a website called Spectral Workbench (<http://spectralworkbench.org/>,

part of the Public Lab project) has appeared that makes the whole process much easier. (This was the source of the spectrometer design). You need to register (free) with Public Lab but that is all!

## Analysing the spectrum

In order to analyse the spectrum and actually get a graph of it, you need to have some reference points. Fortunately, we have these in the form of the spectrum of a fluorescent tube (ideally a compact fluorescent lamp). Usefully, fluorescent lamps have some notable spectral lines that can be used for calibration (Figure 2).

So the first thing to do is to take a photograph of your fluorescent source.

If it's too bright, and that is quite likely if you are pointing it at the source, point it at a piece of white paper or wall which is brightly illuminated by the bulb.

In order for your reference to be valid, make sure you use the same spectroscopy/phone assembly each time and do not zoom in on any of the photographs. Each time you re-attach the spectroscope, you will have to take another reference photo of a fluorescent source.

Once you have logged in to the Spectral Workbench site you will need to upload your image. Click on 'Capture Spectra' (the blue button at the top right, of the screen and the drop down menu gives you the option to upload from file. Selecting this gives you this screen (Figure 3).

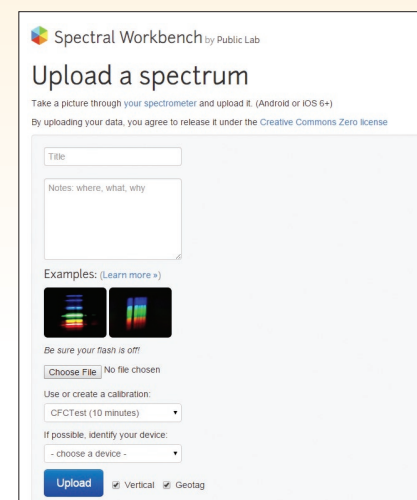


Figure 3 - Spectral Workbench - Upload Screen.

There is a tick box saying 'vertical' but as far as we can tell this makes no difference to how the software analyses your picture.

Enter a name and any other data you need and click the 'upload' button. (Don't worry about the calibration at this point).

After a few seconds, your spectrum will appear - as shown in Figure 4.

If you see a series of horizontal coloured lines rather than a spectrum, click on the 'more tools' button (circled in red on Figure 4).

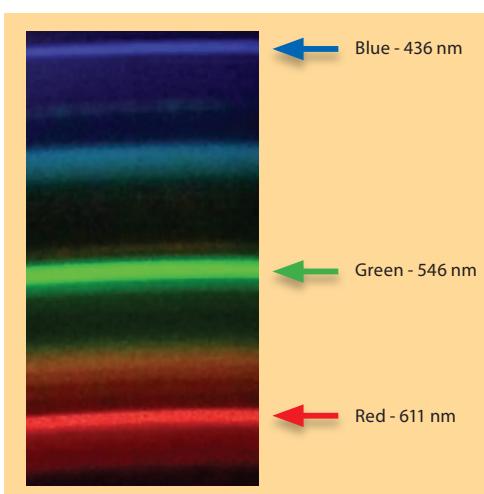


Figure 2 - Spectral lines from a fluorescent lamp.

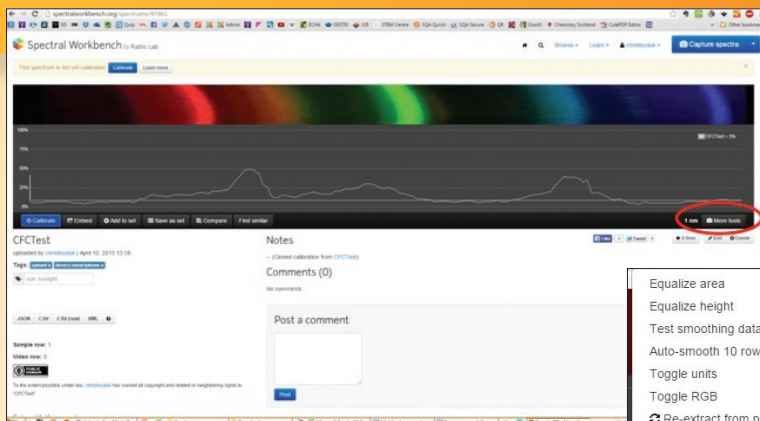


Figure 4 - Spectral Workbench - Spectrum.

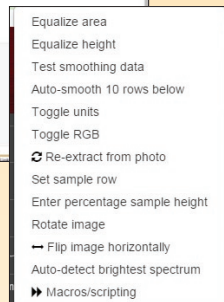


Figure 5 - Spectral Workbench - More Tools Menu.

That brings up a menu (Figure 5).

Click on 'rotate image' and you should soon see something vaguely like the one above.

Another point you need to be aware of is that the analysis software only works if the blue lines are at the left.

If, like in the illustration above, they are on the right, you need to click on 'Flip image horizontally'.

And finally, to get the best graph of your spectrum, click on 'Auto-detect brightest spectrum'.

Now you have your spectrum loaded, you need to set it to be your reference sample.

Click on 'Calibrate' (the blue button on the left below the spectrum) and you will see this screen (Figure 6) appear.

Click 'begin' and then find the brightest part of the appropriate blue band and click.

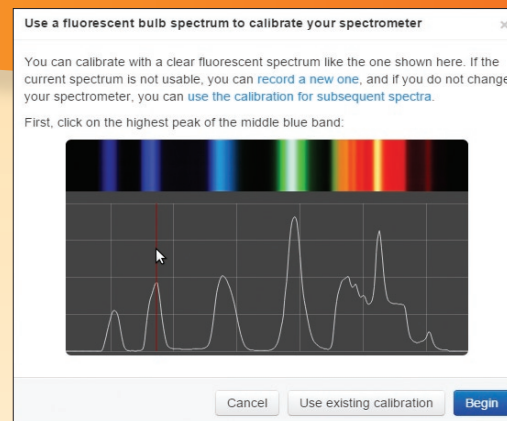


Figure 6 - Spectral Workbench - Calibration.

That brings the screen back, this time telling you to find the brightest part of the green band.

Click on this and after a few seconds your spectrum will reappear with the wavelengths along the bottom.

You will now have something like Figure 7 (which looks very like Figure 4 but you will note there is now a scale along the bottom of the graph).

If you want to get a graph you can print, or otherwise manipulate (to look a bit more impressive), you can export the data. The options are circled in red in Figure 7 - .csv is the best format to choose as it will open directly in Excel.

Once you have exported your data, you can process it to give a much clearer result. Instructions on how to do this are on the SSERC website.

Figure 8 shows an Excel version of the same graph: still with the wavelength along the bottom. (I just used a picture of a spectrum as a background to make it look prettier!).

Now you have your calibration graph, things are much simpler. Upload another image (rotating and flipping it as before if you need to) and the software will automatically interpret it using your reference spectrum. So the graph will appear with the wavelengths along the bottom. The same will be true of all the other spectra you photographed in this session. Here (Figure 9) is one of a white LED (section shown only).

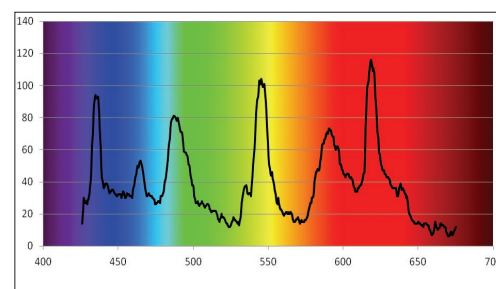


Figure 8 - Spectrum processed in Excel.



Figure 7 - Spectral Workbench - Finished spectrum and exporting.

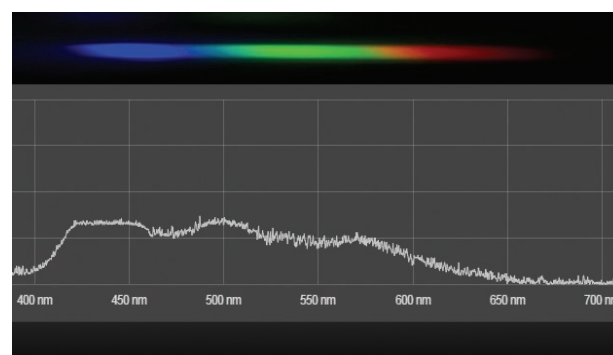


Figure 9 - Spectral Workbench - new spectrum interpreted using the reference photo.

## Radiation Protection Adviser



Radioactivity features in both Chemistry and Physics Senior Phase courses. As a result, most, if not all councils have schools that own low activity radioactive sources.

This makes these councils “Radiation Employers”. Under the Ionising Radiation Regulations 1999, it is a requirement that these employers appoint someone to be their Radiation Protection Adviser (RPA).

The RPA advises on compliance with legislation. In the unlikely event of a council having no schools with radioactive sources, it would still be worth appointing an RPA. It is not uncommon for radioactive artefacts or chemicals to turn up following a clear out in a school.

To become an RPA, a person must undergo certification by an HSE-approved body. Such a person would have spent a number of years working with radioactive sources, have attended training and assisted a qualified RPA. When the legislation first came out, Jim Jamieson of SSERC underwent certification. Jim has now retired. His replacement, Gregor Steele, has now also achieved

RPA status and will act as RPA for all councils, giving advice on the use of radioactive sources in schools. This is included as part of the core SSERC service at no extra charge and fulfils the employer’s legal requirement.

Note that the council has to formally appoint Gregor in writing. SSERC has written to each council, suggesting a form of words and many councils have already replied.

## Risk assessment updates

We note the recent publication of BS 4163: 2014 (*Health and Safety for Design and Technology in Education and similar Establishments - Code of Practice*). Here at SSERC we have been updating our school risk assessments on our website, which are free to download and edit to suit your Technology department. To find them go to; [www.sserc.org.uk/index.php/information-for-technicians55/risk-assessments55](http://www.sserc.org.uk/index.php/information-for-technicians55/risk-assessments55).

