

# STEM bulletin

Supporting STEM for all Local Authorities through advice, ideas and inspiration

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## Educational value of practical work

The reintroduction of Practical Assignments as an assessment component for N5 and Higher Sciences and Projects for Advanced Higher Sciences has some positive benefits – particularly in highlighting the critical role of practical work in introducing learners to scientific ideas and theories.

SSERC recognises the educational value of practical work and believes it should constitute a significant proportion of a learner's time when undertaking a STEM-based curriculum.

We believe that practical work serves the following purposes:

- to motivate and engage learners
- to teach the principles of STEM inquiry
- to develop specialist skills, e.g. measurement, observation
- to underpin the theory through practical skills
- to further develop critical skills and attributes such as communication, teamwork, and creative thinking
- to engage learners to continue the study of science (and STEM).

Teachers and technicians are the cornerstones of good quality practical activity in STEM subjects that take place in schools.



Technicians, in particular, provide a potential untapped pool of knowledge and skills that can and should be further utilised and developed to support practical work to benefit teachers and learners linked to the practical assignment assessment component.

We are aware that this reintroduction has caused some anxiety at a time when some teachers who are new to the profession may not have had much experience in teaching practical skills. More experienced teachers will not have delivered the practical assignment component for some time, and despite reassurances that the assessment specification has not changed, may still be anxious. So, how can we help?

SSERC is a proactive organisation; however, our professional learning calendar is planned approximately a year in advance, so the (late) announcement of the reintroduction of this assessment component and the general anxiety expressed by the profession meant that we had to react to the situation. Across the sciences, we have scheduled various professional learning opportunities to provide support relating to suitable practical assignment contexts. These opportunities will be delivered in a variety of ways:

- Online live webinars
- Self-study courses
- Face-to-face professional learning opportunities at SSERC HQ or other appropriate locations.



For more information, visit our professional learning pages at [Secondary PL - SSERC](#).

It is important to remember that SSERC is not responsible for setting the practical assignment specifications, developing (or interpreting) the marking instructions or responding to any questions linked to these areas. SQA will deal with these aspects at their Understanding Standards events planned for November/December 2023.

We hope that the support from SSERC, combined with the planned SQA Understanding Standards events, will not only provide reassurance to those who have delivered the practical assignment component in the past but also confidence for those where 2023/2024 will be the first delivery occasion.

We are already recalibrating our professional learning calendar for the next academic year to ensure that we provide planned, appropriately timed and new practical assignment ideas to support practitioners (teachers and technicians) for the 2025 practical assignments and project assessment components.

*Alastair MacGregor*

Alastair MacGregor - Chief Executive Officer

## Using a LED as a single photon detector

We came across a very interesting article [here](#) that we thought warranted further investigation. A fuller explanation of the semiconductor physics behind this experiment where the LED is operating in 'Geiger-mode', just beyond its breakdown voltage, is given in the article.

The up-front caveat is that this experiment only works with certain LEDs. From a small drawer of about twenty red LEDs we found one that worked.

The circuit is very easy to set up consisting of a single reverse biased LED in series with two resistors. You will also need a CRO and a 0-25V, continuously variable, smooth DC power supply.

The circuit is shown in Figure 1.

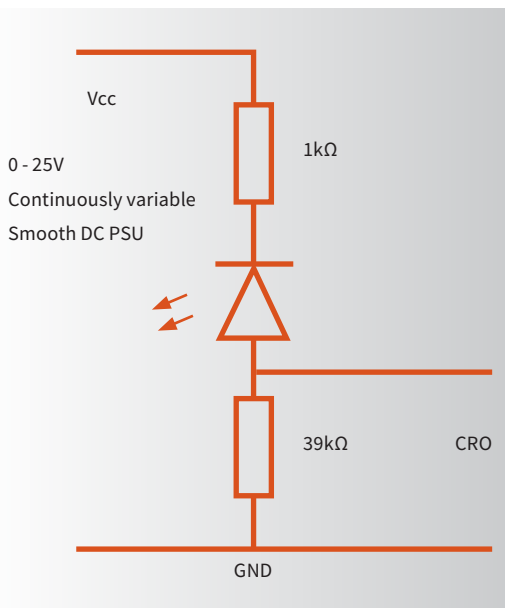


Figure 1 - Circuit diagram.

Set up the circuit as shown then slowly increase the supply voltage. If you have a suitable LED at some point you will see a trace with 'spikes' as shown in Figure 2.

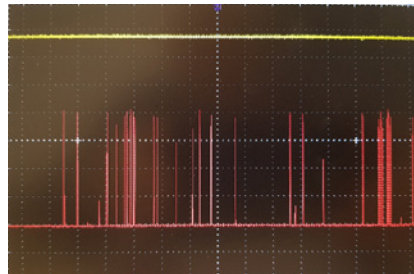


Figure 2 - Initial trace.

At this point it is worth confirming that there are more 'spikes' when it is brighter and fewer when it is darker. Using the CRO we can get a more detailed look at these 'spikes'. Adjusting the timebase we get an image as shown in Figure 3.

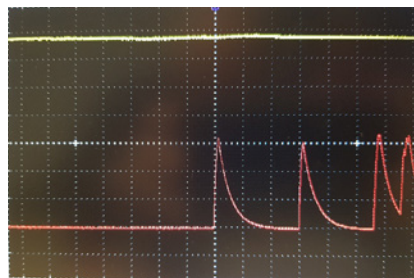


Figure 3 - A more detailed look at the 'spikes'.

In this image we can see the exponential decay nature on the falling edge of the pulse and 'after-pulsing' (where a charge produced during an avalanche is 'delayed' and later triggers a second avalanche) at the right of the image.

An even closer look at the pulse is shown in Figure 4. Here we can also see an initial rounding as the leading edge approaches its maximum value.

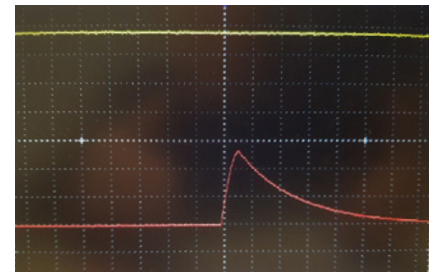


Figure 4 - Rounding of the rising edge.

In Figure 5 we can see that it takes approximately six divisions, each division being 2 μs, for the trailing edge to decay from max to near zero.

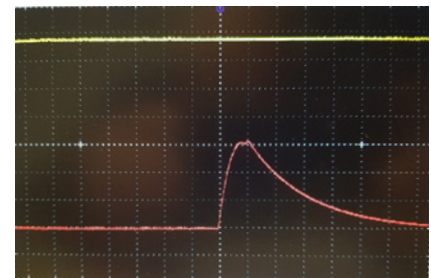


Figure 5 - The decay time.

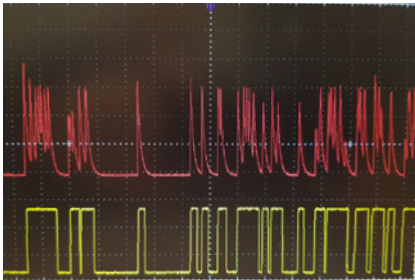
A bit of a simplification, but we can consider the circuit to be that of a capacitor, the capacitance of the LED pn junction, and a series resistor (40 kΩ). Assuming that it takes 5 CR seconds to decay from max to near zero then  $5CR = 12 \mu s$ .  $CR = 12 / 5 \mu s = 2.4 \mu s$ . Taking R as 40 kΩ (1 kΩ + 39 kΩ) gives us an estimated value of 60 pF for the capacitance of the LED pn junction. >>

# Activities & Professional Learning

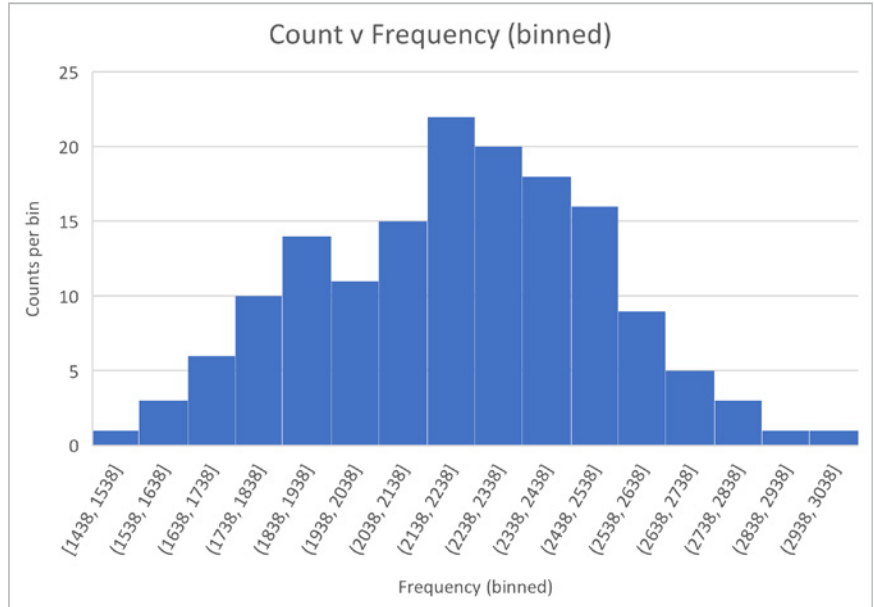
Developing this idea further.

Another excellent article on using LEDs as a single photon detector can be found [here](#).

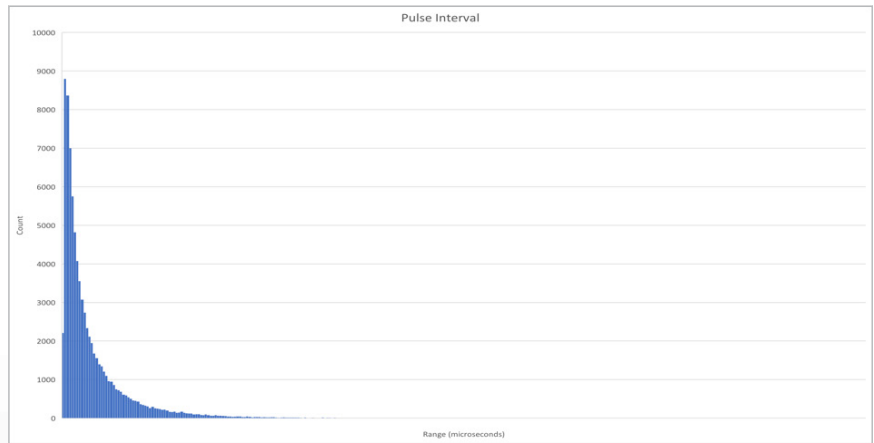
In this article a simple discriminator circuit is added to produce square pulses which are then counted by a microcontroller. Two programs for a Teensy 3.2 microcontroller are provided in the article, one acts as a simple counter (with programmable gate time) and the other records the time interval between successive pulses. Datasets are written to the serial monitor of a computer. Statistical analysis is described for both datasets the latter being analogous to the work done by Rutherford, Geiger and Marsden. <<



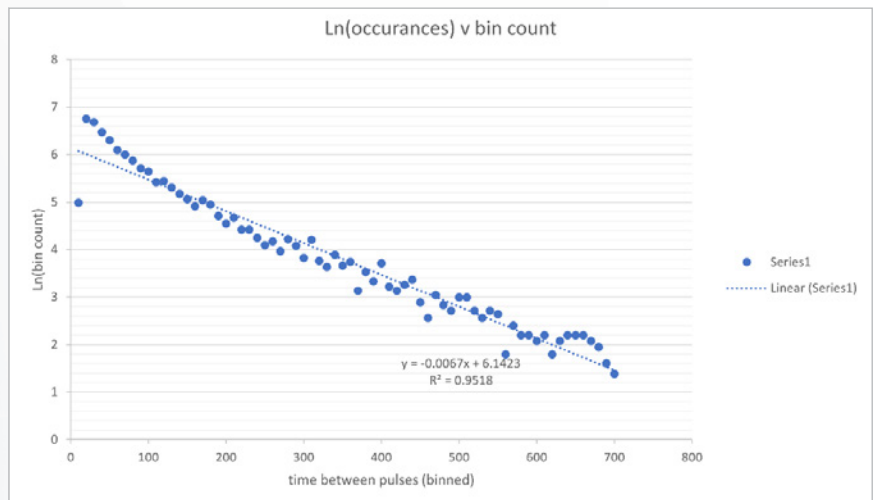
**Figure 6** - Yellow trace shows discriminator output (experiment 3 in link above).



**Figure 7** - Histogram showing 155 data values, mean = 2199.4 (experiment 4 in link above)



**Figure 8** - Histogram of pulse interval data collected over 10 s (> 80 000 values, experiment 5 in link above).



**Figure 9** - Graph of Ln(occurrences) v binned inter pulse time.

## Critical damping demonstration

This article was prompted by a post on Sputnik expressing a desire to demonstrate critical damping.

The work that follows was inspired by the excellent YouTube video demonstration [here](#).

We have recreated the demonstration and then taken it a step further by using the first-rate, free, video analysis software, 'Tracker'. Find it [here](#).

To book a place on our Tracker self-study course please go [here](#).

Click [here](#) to find our tracker support material.

Whilst not necessary we 3D printed a 'pivot' to mount on an 8 mm clamp rod. A simpler arrangement as shown in the [original YouTube video](#) would also work well.

The two, large neodymium magnets were placed either side of a half metre stick.

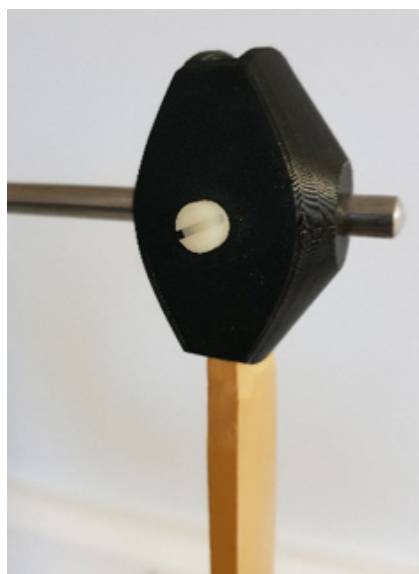


Figure 2 - Pivot details.

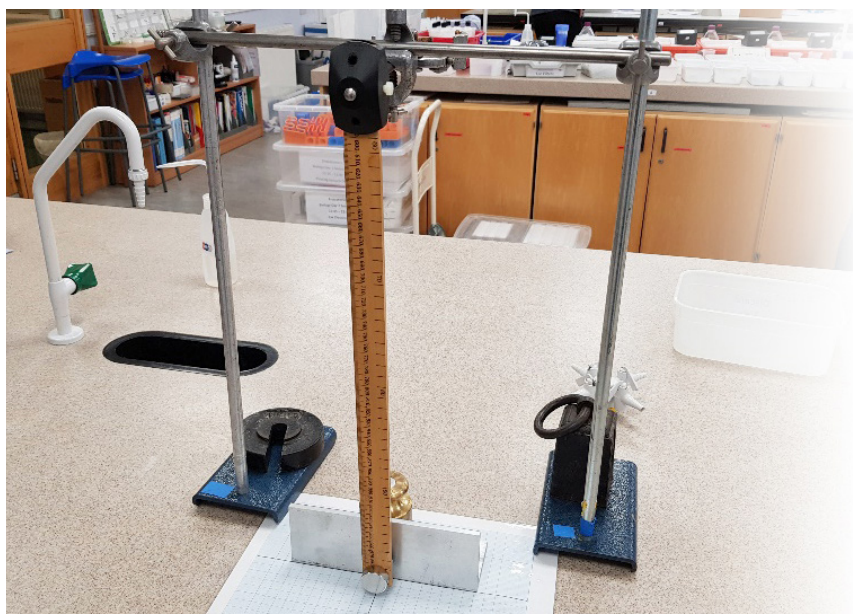


Figure 1 - Experimental set up.

Please be mindful of the pitfalls and health and safety considerations of working with Neodymium magnets; avoid getting them stuck together as it is not easy getting them apart, risk of pinching, risk of fast moving fragments should the magnets be allowed to collide at speed, take care that the magnets do not interfere

with other electrical/electronic devices such as pacemakers, hearing aids and mobile phones etc.

Using a smart phone, videos were taken of the pendulum at various magnet – aluminium separations. When the aluminium is exposed to a changing magnetic field a current is induced in the aluminium. Like any current in a conductor will produce its own magnetic field. Lenz's Law states that the direction of the induced current will be such that it will oppose the change that caused it. These opposing magnetic fields are exploited to produce a braking force. The braking force is dependent on several factors including the magnetic field strength. The closer the magnet to the aluminium the greater the eddy current and the greater the braking force. Where damping is small the pendulum will oscillate about its equilibrium position. At 'critical' damping >>



Figure 3 - Magnets attached to ½ m stick.

# Activities & Professional Learning

the pendulum will approach the equilibrium position in the shortest time without oscillation. Where the damping is large the pendulum will approach the equilibrium position in a much longer time period. The videos were then transferred to a PC and analysed in Tracker.

The data from three runs (2 mm, 8 mm, 30 mm) was then exported from Tracker and imported into Excel where the start times were made to coincide and the data plotted on one graph. This yielded the following results:

The grey (30 mm) trace in Figure 5 was produced with a magnet – aluminium spacing of 30 mm. Here the distance is large and so the induced eddy current and therefore damping force is small. The system is under-damped. The orange trace (8 mm separation) shows the damping force is (near) critical and the pendulum settles to its equilibrium position, without oscillation, in the shortest time interval. The blue trace (2 mm separation) shows over-damping and that the pendulum takes much longer to settle to its equilibrium position.

Our attempt to recreate the excellent video montage at the end of the YouTube video linked to above can be found [here](#).

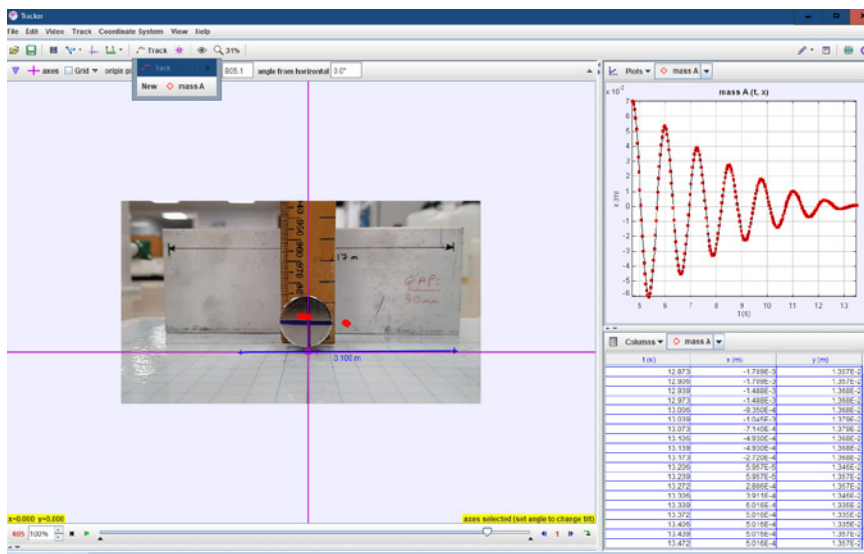


Figure 4 - Tracker screen showing a plot of x position against time.

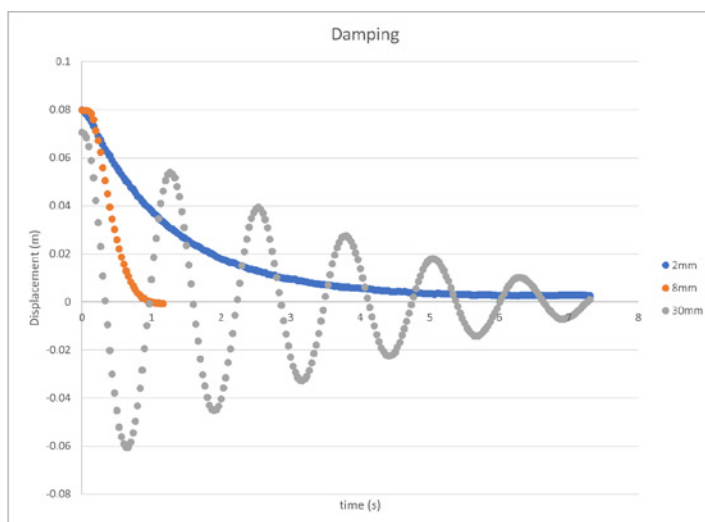


Figure 5 - Combined graph showing under, (near) critical and over damping.

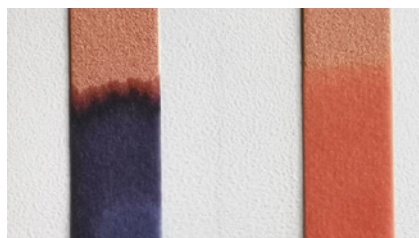
## Indicators

One of the most interesting and appealing topics in the whole of science is that of colour. While the fundamentals of colour are more usually covered in physics, once we get to the colours of materials – paints, dyes and the like, we are firmly in the realms of chemistry.

One group of coloured substances that is widely used from Early Years and Primary up to Advanced Higher and beyond is indicators, which have the benefit of being useful as well as aesthetically pleasing. This article sets out to give an overview of some of the more common types of indicators and their uses in chemistry.

### Acid-base titrations

The most common type of chemical indicator is the acid-base indicator. These have a long history: the Spanish physician Arnaldus de Villa Nova began using litmus to study acids and bases in around 1300 and litmus, a dye extracted from certain species of lichen, has entered the language in general terms to refer to a diagnostic test.



Litmus in acid & alkali.

Litmus is an example of a 'natural' pH indicator and these are more common than might be imagined. Most learners are familiar with the impressive range of colours that can be generated from red cabbage.

However, there are many more natural compounds that change colour in different pH solutions. The largest group of these is the anthocyanins. These are all variations on the same basic structure (see Figure 1) with different groupings present.



Colours of red cabbage acid (l) to alkali (r).

These are the main compounds responsible for the colour of flowers - so many flower petals can be used as indicators. They are also widely found in fruits, particularly the darker ones such as brambles and elderberries.

Other plant materials that can be used as indicators are turmeric (curcumin), tea (theoflavins), beetroot (betanin) and many more.

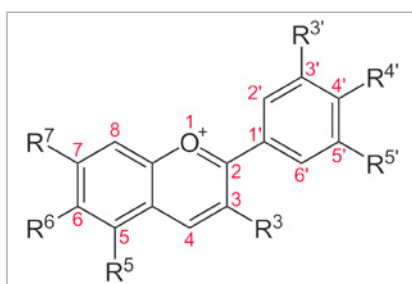


Figure 1 - Generic anthocyanin structure.

### Commercial pH indicators

The pH indicators we use in the laboratory are not extracted from plants though. They are synthesized in a range of ways. Quite a lot of them are types of azo-dyes, though not all.

There are dozens of different indicators and they vary in both their colour changes and the pH at which these take place. Some of the ones that are most commonly encountered in schools are:

- Methyl orange which changes from red in acid to yellow in neutral/alkali at around pH 4.
- Bromothymol blue which changes from yellow in acid to blue in alkali at about pH 7.
- Phenolphthalein which changes from colourless in acid/neutral to bright pink at around pH 9. >>

	0.1 Mol l <sup>-1</sup> HCl <sub>(aq)</sub> (strong acid, pH = 1)	pH 4 buffer (weak acid)	"pure" water (neutral, pH = 7)	pH 9 Buffer (weak alkali)	0.1 Mol l <sup>-1</sup> NaOH <sub>(aq)</sub> (strong alkali, pH = 13)
bromothymol blue (BB)	A1	A2	A3	A4	A5
methyl orange (MO)	B1	B2	B3	B4	B5
Phenolphthalein (PP)	C1	C2	C3	C4	C5

Colours of some common indicators.

# Activities & Professional Learning

## Choosing a pH indicator

Indicators are widely used in acid-base titrations to show the end-point of the reaction. Depending on the nature of the acid and base involved, the pH of the end-point will be different and so different indicators are used.

Looking at these two titration curves (see Figure 2), the one at the top has a mid-point of about pH 7 so Bromothymol blue would be a suitable choice, while the one below it has a mid-point of a lower pH, around pH 5 so methyl red would be a better choice.

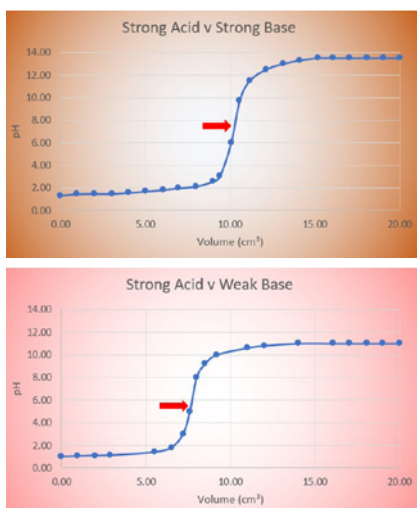
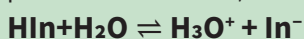


Figure 2 - Titration curves showing different mid-pointse.

## How do pH indicators work?

pH indicators are weak acids. More than that, they have a different colour when protonated than when not. As a weak acid, the indicator will dissociate in solution as shown in this equation. (In = indicator molecule, HIn = protonated indicator)



This dissociation of the weak acid indicator causes the solution to change colour.

The key point here is that this equation describes an equilibrium and as such it is subject to

Le Chatelier's principle. So, if you add acid, you increase the concentration of  $\text{H}_3\text{O}^+$  ( $\text{H}^+$ ) the equilibrium is shifted to the right and as you remove  $\text{H}_3\text{O}^+$  it shifts to the left.

Different indicators have their equivalence points (the 'balance' point of the equilibrium) at different pH values so with change colour at different points.

## Redox titrations

Another main type of indicator is one used for finding the end point of redox reactions. In this case the different coloured forms are the oxidised and reduced form of the substance. Again, like with pH indicators, these two forms are in equilibrium (Figure 3).

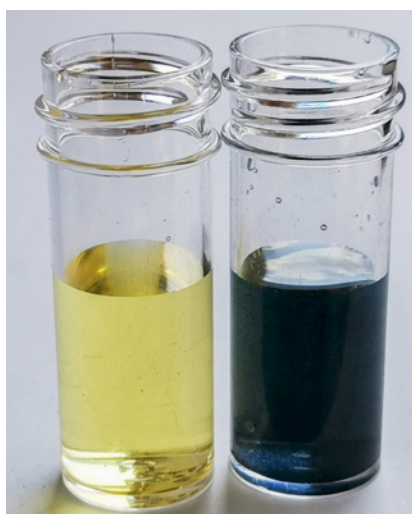


Figure 3 - Iodine (l) and starch-iodine complex (r).

In this case, the indicators change colour at a specific electrode potential rather than pH, although some are pH dependent as well. Many redox titration, however, especially those carried out in schools and colleges, do not use separate indicators. They rely on colour changes inherent in the reaction.

For instance, titrating a reducing agent with a solution of iodine (yellow/brown) to produce iodide (colourless). Starch is usually used as an indicator to assist in the visualisation of a clear end-point though this is not actually a redox indicator.

Another example is titrating with potassium manganate VII, using the inherent purple colour of the permanganate ion as the indicator.

## Compleximetric titrations

The third class of indicators include the starch mentioned above. In this class, the end point of the titration is indicated by the formation or dissolution of a sudden complex. The most common type of titration uses EDTA (ethylenediaminetetraacetic acid) as a titrant to determine a variety of metal cations: calcium and magnesium concentrations in water is a common experiment.

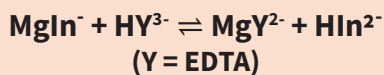
The reaction depends on the relative stability of different complexes. The indicator is added to the solution. For calcium or magnesium, murexide is a common one (Figure 4). This forms a red complex. The solution is >>



Figure 4 - Colour changes of murexide/magnesium complex (l) and uncomplexed murexide (r).



then titrated with EDTA. EDTA forms a more stable complex with the metal ions and so abstracts the metal leaving the non-complexed form of the indicator, which is blue.



By varying the indicator and the pH at which the titration takes place, it is possible to vary the relative stability of the metal-indicator and metal-EDTA complexes.

### Precipitation titrations

In this case, the titration involves the formation of a precipitate during the experiment. The titration is continued until the last of the precipitate is formed. At that point any excess titrant reacts with an indicator causing a colour change. The best-known example of this sort of titration is an argentometric titration, which is used to investigate the concentration of chloride (or other halides) by titration with silver nitrate (Figure 5). As the reaction

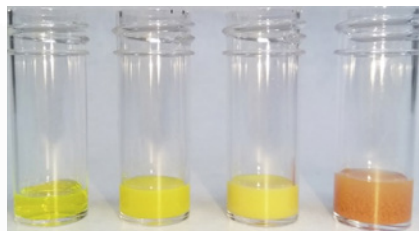


Figure 5 - Silver-chloride titration using fluorescein (Farjan's method).



Figure 6 - PH Lizard made from drops of red cabbage indicator.

proceeds, a precipitate of the silver halide is formed. Mohr's method uses potassium chromate as an indicator which forms red silver chromate at the end point. Farjan's method is similar but uses fluorescein dye that changes from yellow to pink at the endpoint.

### Indicators and Art

It is possible to use the lovely colours generated by indicators for artistic purposes – a sort of pH related painting by numbers. There are some lovely examples, including the one here, in an [article by Isobel Everest in Chem 13 News](#) from a few years ago (Figure 6).

### In conclusion

We have barely scratched the surface of this topic and as you can see there is a plethora of indicators that can be chosen from for a wide variety of purposes. Details of many, can be found on the [SSERC website](#) and if you need details of ones we don't list, just get in touch. <<

## SSERC professional learning courses

We offer professional learning (PL) courses and events for teachers in both primary and secondary settings, school technicians, and other educators. Many of our PL offers are financially supported via ENTHUSE funding from STEM Learning or from the Scottish Government. Such funding for our courses helps towards covering course costs and allows us to provide delegates with resources to support learning and teaching back in their schools.

Courses available for online booking include:

COURSE NAME	RESIDENTIAL?	DATES	CLOSING DATE	SECTOR
<b>*Technology Probationers</b>	Face-to-face	9-10 November 2023	2 October 2023	Secondary Technology
<b>*Safety in Microbiology for Schools</b>	Face-to-face	14-16 November 2023	2 October 2023	Secondary Technicians
<b>*Hot and Cold Metal</b>	Face-to-face	16-17 November 2023	2 October 2023	Secondary Technology***
<b>Safe Use of Fixed Workshop Machinery</b>	Face-to-face	21-22 November 2023	20 October 2023	Secondary Technicians**
<b>Intermediate Physics</b>	Face-to-face	22-23 November 2023	20 October 2023	Secondary Technicians
<b>*Laboratory Science Nat 5</b>	Face-to-face	5-7 December 2023	4 November 2023	Secondary Science
<b>Safe Use of Fixed Workshop Machinery (Refresher)</b>	Face-to-face	12 December 2023	10 November 2023	Secondary Technicians**
<b>Biology SSERC Meet</b>	Online	14 December 2023	8 December 2023	Secondary Biology***
<b>Science Probationers Residential</b>	Face-to-face	19-20 December 23	11 November 2023	Secondary Science
<b>Science Probationers Residential</b>	Face-to-face	17-18 January 2023	30 November 2023	Secondary Science
<b>Safe Use of Fixed Workshop Machinery</b>	Face-to-face	17-18 January 2023	30 November 2023	Secondary Technicians**
<b>Science Probationers Residential</b>	Face-to-face	24-25 January 2023	8 December 2023	Secondary Science
<b>Safe Use of Fixed Classroom Machinery</b>	Face-to-face	24-25 January 2023	8 December 2023	Secondary Technology
<b>*Chemistry for Advanced Higher</b>	Face-to-face	22-23 February 2023	5 January 2023	Secondary Chemistry
<b>*Wood Turning</b>	Face-to-face	22-23 February 2023	5 January 2023	Secondary Technology***
<b>Safe Use of Fixed Classroom Machinery</b>	Face-to-face	28-29 February 2023	12 January 2023	Secondary Technology
<b>Chemical Handling</b>	Face-to-face	5-6 March 2023	2 February 2023	Secondary Technicians
<b>Electrical Safety and PAT</b>	Face-to-face	7-8 March 2023	2 February 2023	Secondary Technicians
<b>*Techniques for Senior Phase Biology</b>	Face-to-Face	12-13 March 2023	26 January 2023	Secondary Biology
<b>Biology SSERC Meet</b>	Online	20 March 2023	13 March 2023	Secondary Biology***
<b>*Centre Lathe Turning</b>	Face-to-face	26-27 March 2023	24 February 2023	Secondary Technology***
<b>Self-Study online courses</b>	Self-study	29 March 2023	29 February 2023	Secondary Science***

\* This course attracts ENTHUSE funding which offsets the course fee.

\*\* May also be suitable for secondary teachers.

\*\*\* May also be suitable for secondary technician.

Please check our website pages at <https://www.sserc.org.uk/professional-learning/calendar/> for the most up-to-date details on our professional learning calendar.

## Phosphorylase - moving from N5 to AH

Phosphorylase, extracted from potatoes, is an enzyme that has been used in many classrooms to exemplify a synthesis reaction. The enzyme, found in several higher plants, catalyses the reversible transfer of glucosyl units from glucose-1-phosphate (substrate) to the non-reducing end of  $\alpha$ -1,4-D-glucan chains with the release of phosphate, forming starch (Figure 1). The production of starch can be monitored by the addition of iodine, forming a blue-black complex.

This practical activity is particularly relevant at National 5 Biology level, with the SQA course specifications outlining a requirement for learners to understand that “enzymes can be involved in degradation and synthesis reactions” (Figure 2).

In this bulletin, we provide progression for learners working at Advanced Higher level through the inclusion of colorimetry and the production of a standard curve to estimate the concentration of starch synthesised during the reaction, supporting Key Area 1b of Cells and Proteins (Figure 2).

### National 5 Biology

Candidates must become familiar with the techniques to measure enzyme activity.

Key area 4b: Required knowledge includes “enzymes can be involved in degradation and synthesis reactions”.

A suggested learning activity is to “investigate the action of potato phosphorylase”.

### Advanced Higher Biology

In the course specification, Key Area 1b states that the learner must understand:

- ★ the method and uses of a colorimeter
- ★ know how to produce a standard curve to determine an unknown.



Figure 2 - Curriculum links relevant to this investigation.

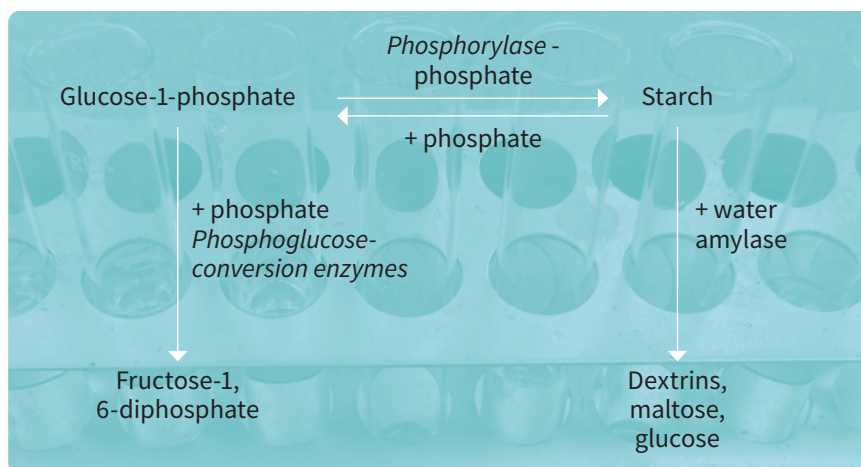


Figure 1 - An overview of the role of phosphorylase in metabolism. Image adapted from (1).

### Aim

The aim of this investigation is to extract an enzyme from biological material and investigate the enzymatic synthesis of starch.

### Materials and method

In the first part of this investigation, phosphorylase must be extracted from potatoes. This requires the materials outlined in Figure 3.

Approximately 50 g chopped and peeled potato must be blended with sufficient water to form a slurry. After passing through muslin, the filtrate must be centrifuged (> 3000 rpm for 5 minutes) and the supernatant collected (contains the enzyme). Centrifugation separates the enzyme from starch granules; this should be confirmed by taking a drop of supernatant and combining



### Materials

- potato
- knife, chopping board, vegetable peeler
- blender
- muslin
- beaker
- centrifuge
- centrifuge tubes & rack
- container to store extract
- 3 cm<sup>3</sup> plastic pipettes
- 0.01 M iodine solution
- simple tile

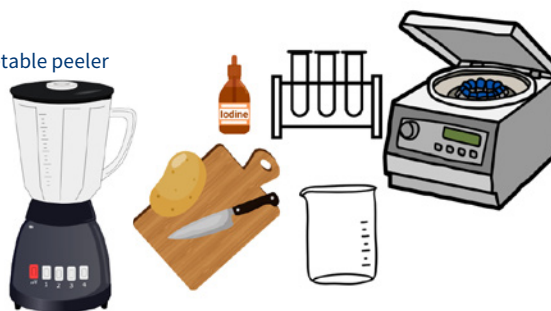


Figure 3 - Materials required for part 1.

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it with a drop of iodine on a dimple tile. If there is a blue/black colour, centrifuge the sample for longer. The supernatant will discolour over 24 hours so should be prepared fresh.

The next part of the investigation focuses on the phosphorylase assay. The following steps are required:

- 1) Set up 7 cuvettes. To cuvette 1, add 3 cm<sup>3</sup> water (to zero the colorimeter). To cuvette 2-7, add 1 cm<sup>3</sup> water and 1 cm<sup>3</sup> iodine.
- 2) Collect 2 test tubes. To test tube 1 (colorimetric blank), add 1 cm<sup>3</sup> enzyme and 1 cm<sup>3</sup> water. To test tube 2, add 5 cm<sup>3</sup> enzyme and 5 cm<sup>3</sup> 1% glucose-1-phosphate. Immediately start the stopwatch and incubate reactions at room temperature.
- 3) After 2 minutes, transfer 1 cm<sup>3</sup> from test tube 2 to cuvette [3].
- 4) After 60 s, transfer 1 cm<sup>3</sup> from test tube 2 to cuvette 4.
- 5) Repeat step 4 every 60 s.
- 6) Measure the absorbance of the samples. Using the red diode (or approximately 600 nm), zero the absorbance reading using the cuvette of water. To cuvette 2, add 1 cm<sup>3</sup> of the colorimetric blank (test tube 1). This should be recorded as 0 s time point.
- 7) Measure the absorbance of each sample.

Sample results for this investigation are shown in Figure 6. The assay was carried out in triplicate and



Figure 4 - Materials required for Part 2 of the investigation.

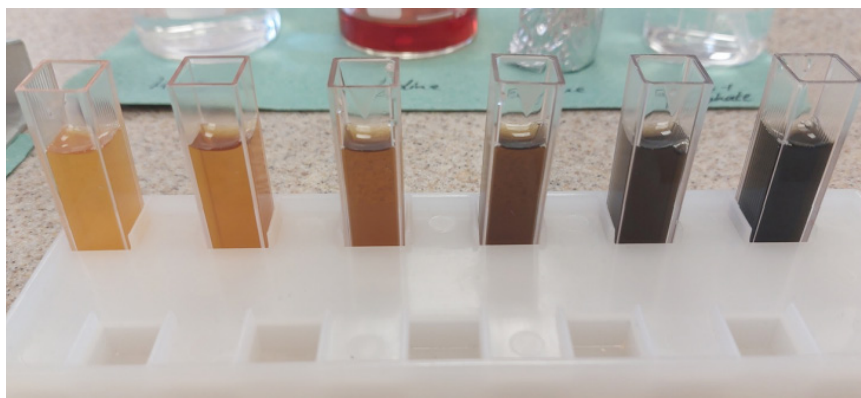


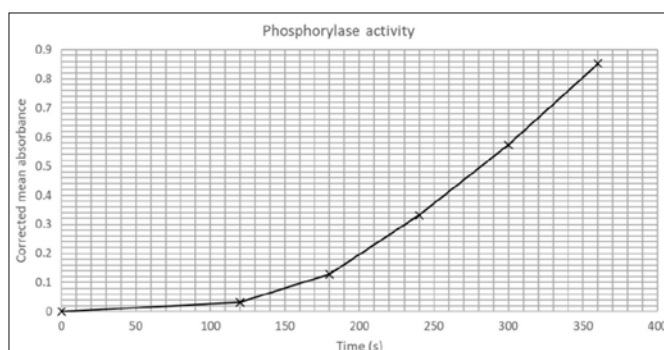
Figure 5 - Synthesis of starch from glucose-1-phosphate by phosphorylase over 5 minutes.

mean values calculated. The mean absorbance value obtained at 0 s was subtracted from remaining absorbance values since this

reflected the absorbance of the enzyme alone, not the production of starch, and would be present in all samples. >>

Time (s)	Absorbance				
	Trial 1	Trial 2	Trial 3	Mean	Corrected mean
0	0.206	0.203	0.207	0.207	0.000
120	0.229	0.232	0.240	0.240	0.033
180	0.327	0.334	0.336	0.336	0.129
240	0.567	0.514	0.533	0.538	0.331
300	0.769	0.769	0.783	0.780	0.573
360	1.082	1.065	1.032	1.060	0.853

Figure 6 - Results obtained from the phosphorylase assay.



# Activities & Professional Learning

## Materials

- 0.01 M iodine
- colorimeter (red diode)
- 9x cuvettes and rack
- 8x test tubes and rack
- 0.1 mg/ml starch suspension
- 0.2 mg/ml starch suspension
- 0.3 mg/ml starch suspension
- beaker of distilled water
- 1 cm<sup>3</sup> automatic pipette and tips
- 10 cm<sup>3</sup> measuring cylinder
- 3 cm<sup>3</sup> plastic pipettes

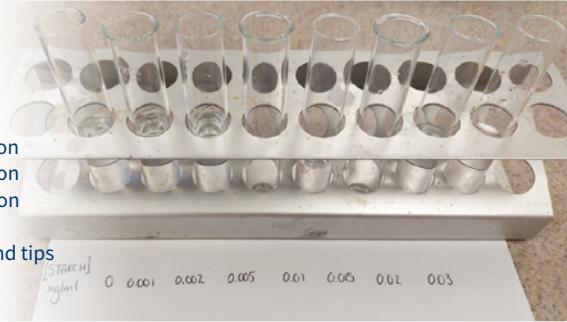


Figure 7 - Materials required to produce a starch standard curve.

## Production of a standard curve

To extend this investigation for learners working at Advanced Higher level, a standard curve of starch can be plotted from which estimates of starch concentration synthesised during the phosphorylase assay can be made. Learners can develop their skills using measuring instruments to accurately prepare a dilution series of starch. These are then combined with iodine and the absorbance measured (Figure 7).

Learners should prepare a dilution series of starch to include concentrations of 0.001, 0.002, 0.005, 0.01, 0.015, 0.02 and 0.03 mg/ml starch. Once prepared, the following steps should be taken:

- 1) Collect 8 cuvettes: to cuvette 1, add 3 cm<sup>3</sup> water (to zero the colorimeter); to cuvette 2-8, add 1 cm<sup>3</sup> water and 1 cm<sup>3</sup> iodine.

- 2) To cuvettes 2-7: add 1 cm<sup>3</sup> appropriate starch suspension, working from the most dilute to the most concentrated.
- 3) Set the colorimeter to the red diode (or approximately 600 nm). Zero the colorimeter using the cuvette of water and then measure the absorbance of each solution.

Plot the results on graph paper or using a suitable graphing program, such as Excel. Add a line of best fit (hand-drawn graphs) or trendline (Excel). See Figure 9.

The data collected during the phosphorylase assay can be processed to estimate the starch concentration in each sample, as a result of phosphorylase action on the substrate glucose-1-phosphate. This can be done using the equation of the trendline of the standard curve.

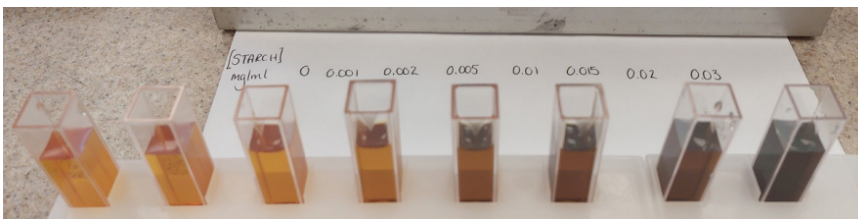


Figure 8 - A standard curve for starch can be produced from a suitable dilution series.

Starch Concentration (mg/ml)	Absorbance
0	
0.001	
0.002	
0.005	
0.01	
0.015	
0.02	
0.03	

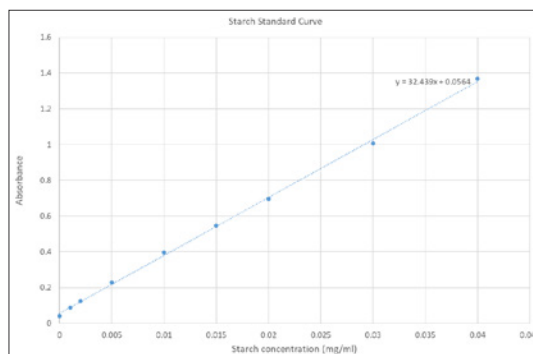


Figure 9 - Standard curve for starch.

Figure 10 provides sample results obtained at SSERC.

This protocol is available via the SSERC website, providing a breakdown of relevant calculations, support with the dilution series and technical support [2].

Time (s)	Starch concentration (mg/ml)	Starch concentration (µg/ml)
0	0	0
120	0	0
180	0.002	2.2
240	0.008	8.5
300	0.016	15.9
360	0.025	24.5

Figure 10 - Concentration of starch synthesised by phosphorylase from glucose-1-phosphate over 6 minutes.

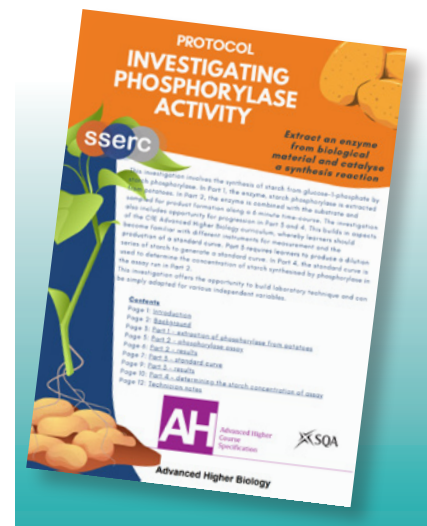


Figure 11 - SSERC's latest phosphorylase assay resource.

## References

- [1] Hanes, C.S. (1940), The reversible formation of starch from glucose-1-phosphate catalysed by potato phosphorylase, The Royal Society Publishing, available at <https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.1940.0035>.
- [2] SSERC (2023), Investigating phosphorylase activity, available at <https://www.sserc.org.uk/wp-content/uploads/2023/08/Protocol-Phosphorylase-Activity.pdf>.

## The Young STEM Leader Programme is growing...



Ever since the launch of the STEM Strategy back in 2017, there has been a demand for an SCQF Level 7 version of the Young STEM Leader Programme. SSERC is excited to announce that this demand is now being met.

### SCQF Level 7 Award in STEM Leadership

With the support of Ocean Winds and the SCQF Partnership, SSERC has developed a new Award in STEM Leadership at SCQF Level 7. This new level of YSLP is designed for colleges, senior phase learners and community settings with a specific focus on Learning for Sustainability and the UN Sustainable Development Goals.

Taking part in the award will comprise learners undertaking a research project, with assessment being holistic and based on project outputs – rather than the traditional Young STEM Leader Log.



Across academic year 2022/2023, a small writing and development group was formed consisting of existing Tutor Assessors and representatives from colleges, SQA and Zero Waste Scotland to produce an initial award framework, outlining the six Learning Outcomes that STEM Leaders will achieve as part of a project-based qualification.

As of August 2023, SSERC is undergoing the credit rating process with SQA.

Over twenty centres have been recruited to take part in a limited award pilot starting in September 2023. The award will be available to all centres starting in June 2024.

For more information or to get involved with YSLP visit: <https://www.youngstemleader.scot/> <<

 <b>1</b> Evaluate and improve their own leadership skills and qualities	 <b>2</b> Identify a research project question considering Learning for Sustainability and the UN Sustainable Development Goals	 <b>3</b> Appraise how an identified individual, group or organisation can support their project as a mentor/coach/advisor	 <b>4</b> Develop a method and timeline to gather evidence for their project question	 <b>5</b> Gather, analyse and review results	 <b>6</b> Present the conclusions of the project
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## Wash and glow - visualising the spread of bacteria

SSERC received an enquiry recently about a practical activity designed to simulate the spread of bacteria. Learners spread a commercially available “lotion”, containing microscopic particles that fluoresce when exposed to UV light, over their hands and then shake hands with their peers in the classroom. During this process, lotion will be transferred between learners, simulating the spread of microbes. To determine the extent to which transfer has occurred, learners irradiate their hands with a UV light.

SSERC have produced guidance on optical radiation [1], which is pertinent to this activity. The majority of the radiation emitted from the type of lamps typically used in this activity is UVA, which poses hazards to the eyes and skin. SSERC have carried out various tests and found that the exposure limits for emissions from such lamps are unlikely to be breached in a school lab provided that:

- Users avoid looking directly at the lamp
- Users do not hold or carry the lamp with their hands or fingers across the tube when the lamp is on
- Users avoid irradiating their skin where possible.

Given the requirement for learners to irradiate their hands with UV light to visualise the lotion, the activity does not adhere to SSERC guidance. Figure 1 shows a hand-held UV light that might be used in such an activity; there are other types of UV lamp that might be used, which can have more stringent control measures.

A straight-forward, although messy, alternative to this proposed activity is to use glitter gel; learners spread a glitter gel over their hands, shake hands and then observe the transfer of glitter. This ultimately shows the same result but without the need to use UV light.

Another alternative option involves learners each starting with a test tube of water – except one learner, who has a suspension of starch (with starch representing a microbe). The “transfer of bodily fluids” involves each learner using a pipette to exchange half of their test



**Figure 1** - Guidance states that individuals must not carry UV lamps with fingers across the tube.

tube contents with another learner. This can continue for 3-4 exchanges. At the end, they all test their samples using iodine to find out how far the starch/microbe spread. Inexpensive, safe, fun and still conveys the same message. <<

### Reference

- [1] SSERC, School sources of optical radiation, available at <https://www.sserc.org.uk/health-safety/physics-health-safety/optical-radiation/school-sources-of-optical-radiation/>.

## HSE radiation inspections

In Bulletin 276 [1] last summer, we reported that the Health and Safety Executive (HSE) intended to inspect a sample of schools throughout the UK to check whether their use and storage of radioactive materials complied with the Ionising Radiation Regulations (IRR17). In the period November 2022 to March 2023, 16 Scottish schools were visited.

The SSERC team had a number of meetings with HSE personnel before and after the inspections. The following is a summary of what they found out, what is happening now and what happens next.

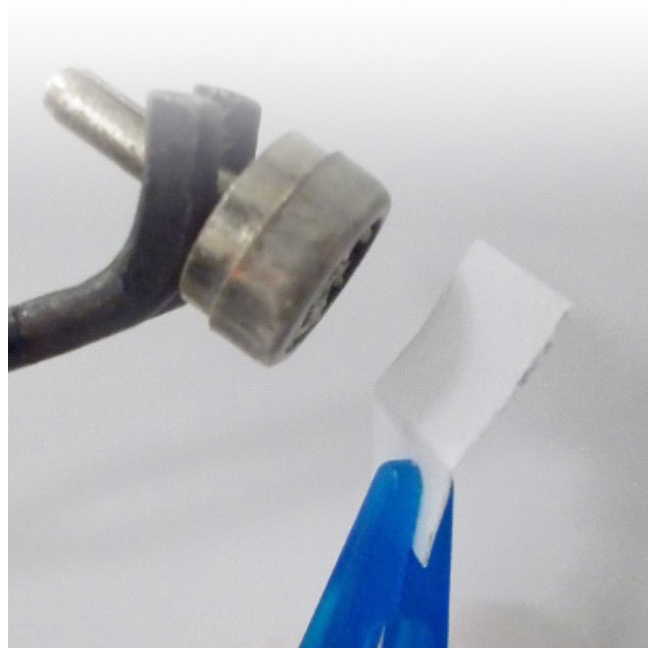
### Findings

Compliance rates – the percentage of schools where no breaches were found - were quite high when compared with other sectors. There were, however, issues in some schools, resulting in employers being both fined and required to produce a plan detailing how they would deal with shortcomings. Schools that were following SSERC guidance were compliant. According to one inspector, the situation in Scotland was “all or nothing”. Schools were either exemplary or were doing virtually none of the tasks – stock checks, leak tests etc. that are required by law. Interestingly, all of the non-compliant schools were aware of SSERC advice and knew that they could contact us for help. It appears that the greatest cause of non-compliance was that when a member of staff who had been responsible for supervising work with radioactive materials moved on, nobody else picked up the mantle. Out of date training was also a significant issue. We must say that at no point did we feel that inspectors were failing schools for petty nit-picks. Indeed, any feedback we received about the inspection process was positive. Words like “supportive” and even “kind” were used.

### What is happening now?

We will be modifying some of our guidance as a result of the inspections.


- When carrying out a stock check, please list, on the log of usage, the individual sources that were checked.
- HSE expect all those using radioactive materials to be trained every 3 to 5 years. Whilst this could be inhouse, the member of staff responsible for overseeing work



A source undergoing a leak test.

with these materials, called the RPS by many schools, should have SSERC training at this frequency too. This could be via one of our online courses, but if the RPS has never had direct training on safe handling using actual sources, they should attend a face-to-face training event. If employers wish to run their own safe handling training this must be sanctioned by SSERC.

- Though not a modification to our guidance, we would like to again stress that any risk assessments or contingency plans supplied by SSERC must be modified to suit local circumstances. >>

 <b>SSERC Example Risk Assessment for Teacher Demonstration Using an Am-241 Hi Tech Sealed Source with an Activity of 74 kBq</b> <small>This example risk assessment should be adapted for your own particular circumstances.</small>		
Activity assessed	Teacher Demonstration Using an Am-241 Hi Tech Sealed Source with an Activity of 74 kBq	
Date of assessment		
Date of review		
School		
Department		
Employer		
<b>List significant hazards here:</b> Exposure to ionising radiation due to storage of radioactive sources.	<b>Who might be harmed and how?</b> Teachers, Technicians, Pupils, Other employees who may work in the vicinity of the store. Exposure to ionising radiation can cause deterministic and stochastic effects.	<b>Control measures (what is being done to make the risk tolerable)</b> When not in use sources are kept (within their storage receptacles) in a secure storage cabinet which is in a suitable location - minimum distance to a pupil work station 1.5 m, teacher work station 2.5 m, technician workstation 3 m. (Or if shielded by a brick - minimum distance to a pupil work station 1 m, teacher work station 2 m, technician workstation 2 m.) Gamma sources are stored at least 20 cm back from the storage cabinet door and any accessible sides (or shielded with a brick).

Generic SSERC risk assessments must be customised.



SSERC produces guidance and helps school staff implement it via our training and help-lines, but it is the employer's duty to see that our advice is being followed. Several local authority personnel have been in touch with us for advice on making non-compliant schools compliant. We have also had enquiries on how to carry out inhouse inspections and have supplied checklists linked to our own documentation. These employer-led inspections have highlighted some additional issues.

- The only radioactive materials you should have in school are the ones detailed in Bulletin 256 [2]. Some schools are finding uranium and thorium compounds, usually in small amounts. Unfortunately, even small quantities can be tricky to dispose of, but you do not have an option to keep them.
- You are allowed to keep an ionisation chamber smoke alarm to demonstrate that it contains a radioactive source. On no account should the device be dismantled. To do so without a permit from SEPA, the environmental agency, would be a breach of law. If you have a dismantled smoke alarm that you cannot put back together, disposal can be difficult as it is subject not only to radiation laws but to waste electrical equipment legislation. "Difficult" is, fortunately, not the same as "impossible". Again, keeping a dismantled smoke alarm is not an option.
- Another item you must dispose of is a protactinium generator that is 8 years old or more. Disposal is expensive, but if an aged generator leaks and contaminates the fabric of a school building, failing to dispose will prove to be the falsest of false economies.

So far, no employer inspection has discovered any aged protactinium generators, but we believe there are a very small number of them "out there".

We have every sympathy for staff who discover sources that should not be in schools. In almost every case, it is an inherited problem. If you discover a source that is not on our approved list, please get in touch. Remember that you should not buy or acquire any radioactive materials or artefacts without consulting SSERC.

### What happens next?

HSE will continue to inspect schools. If you get notification of an inspection, please let us know and we will work with you to help you ensure that everything is in order. Note that, even if you have no sources but have possessed some in the last two years, in theory HSE could still inspect your records which you must retain for that period. HSE have also been asking about radon in schools. Whilst that is not the responsibility of teaching and technician staff, we have some basic guidance available on request. It might be worth highlighting this to your senior management, particularly if you are not in a local authority school.

It is our view that, in Scotland, the inspections have had a largely positive effect, raising awareness of the need to comply with legislation and emphasising SSERC's role in helping you to do so. <<

### References

- [1] <https://www.sserc.org.uk/wp-content/uploads/2022/06/Bulletin-276p18-Radioactivity-inspections.pdf>
- [2] <https://www.sserc.org.uk/wp-content/uploads/2020/08/256-Auditing-Radioactive-Sources.pdf>

## Quick disposable dust mask guidance

The purpose of disposable dust masks is to provide a means of controlling airborne contaminants in the air that could be inhaled by an individual. Under COSHH regulations, employers are required to provide employees with suitable personal protective equipment where necessary. This is in addition to other control measures such as dust extraction systems found within the technology department.

Any dust mask or other form of respiratory protection should limit the exposure to contamination (i.e. wood dusts) to a level that is as low as reasonably practicable and below the workplace exposure limit set for the type of substance. For example, the WEL hardwood dust is 3mg/m<sup>3</sup> and 5mg/m<sup>3</sup> for softwood. Both being based on an 8-hour time-weighted average.

### So what types are available and what should be used?

#### Not suitable for technology departments

##### Nuisance dust masks

A nuisance dust mask (Figure 1), is a type of disposable mask that provides basic protection against larger non-toxic particles in the air. These masks are designed to be lightweight, comfortable, and affordable, making them suitable for tasks where the primary concern is general dust and particulate matter rather than hazardous or toxic substances. Nuisance dust masks are only suitable for environments where the particles present are not toxic or harmful to health.

##### FFP1 & FFP2

An FFP1 or FFP2 mask (Figures 2 and 3), is a type of disposable face mask that provides minimal protection against non-toxic particles. FFP stands for "Filtering Face piece Particle" and the number preceding it indicates the level of filtration efficiency. FFP1 masks are the lowest level of respiratory protection among the FFP masks.

FFP1 masks are designed to filter out at least 80% of airborne particles with a size of 0.3 microns or larger. They provide basic protection against larger dust particles, pollen, and other non-toxic particulate matter.



Figure 2 - FFP1 mask.

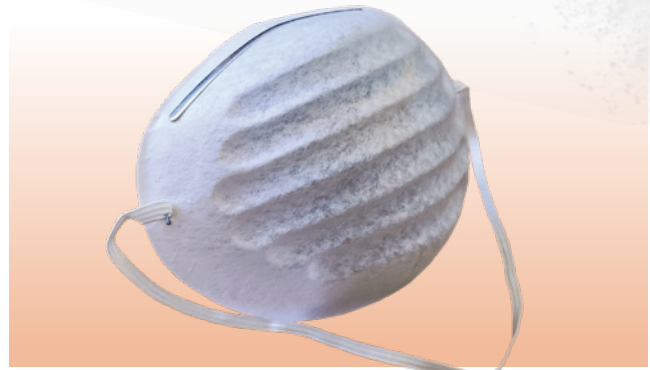


Figure 1 - Nuisance dust mask.

FFP2 masks are designed to filter out at least 94% of airborne particles with a size of 0.3 microns or larger. They provide better protection against fine dust particles, aerosols, and certain types of hazardous particles.

While FFP1 and FFP2 masks offer some level of protection, they do not provide a tight facial seal like more advanced respirators. As such, they may not be effective in situations where a secure seal is required to prevent particle leakage around the edges of the mask. FFP1 and FFP2 masks are typically disposable and designed for single-use applications. They are not meant to be reused and should be discarded after use.

#### Suitable for technology departments

##### FFP3

FFP3 masks (Figure 4) are designed to offer maximum protection against airborne particles, including fine dust, aerosols, and hazardous substances. They are designed to filter out at least 99% of airborne particles with a size of 0.3 microns or larger. They offer excellent protection >>



Figure 3 - FFP2 mask.



Figure 4 - FFP3 mask.

against fine particles, including those that could be harmful to health. They are suitable for environments where the particles present are highly hazardous and can pose significant health risks.

FFP3 masks provide a better and more secure facial seal compared to lower-level FFP masks. A proper fit and seal are critical to preventing particle leakage around the edges of the mask.

Face fit testing should be performed to ensure that the mask properly fits the wearer's face and minimises the risk of airborne contaminants leaking in around the edges of the mask and therefore reducing its performance and putting the user at risk.

These masks are typically disposable and intended for single-use applications. They should be discarded after use to ensure consistent protection.

When using FFP3 masks, it's crucial to ensure that they are certified by reputable standards organisations to ensure their effectiveness (such as CE or BSI markings). Proper use, fit, and disposal are essential for maximising the protection provided by FFP3 masks. Keep in mind that while FFP3 masks offer a high level of protection, they are not a substitute for other safety measures, and other personal protective equipment (PPE) may be necessary depending on the specific hazards present.

### Half-mask/full-face respirator

Both half-mask and full-face respirators (Figure 5) are types of respiratory protective equipment designed to provide different levels of coverage and protection for the wearer's face and respiratory system.



Figure 5 - Half-mask and full-face respirators.

A half-mask respirator covers the lower half of the wearer's face, including the nose and mouth. Whereas a full face respirator covers the entire face, including the eyes, nose, and mouth.

They both typically use a filter cartridge or canister to provide protection against specific types of hazards, such as particulates, gases, or vapors. In the case of wood dusts, FFP3 filter cartridge can be fitted.

Half-mask respirators are often lightweight and more comfortable for extended wear compared to the traditional disposable masks.

The choice between a half-mask and a full-face respirator depends on the specific hazards present in the environment, as well as the comfort and protection needs of the wearer. It's important to follow manufacturer guidelines, undergo proper fit testing, and receive training on how to properly use and maintain the chosen respirator.

### Powered visor respirator

A powered visor respirator (Figure 6), also known as a powered air purifying respirator (PAPR) with a visor, is designed to provide respiratory and eye protection. It consists of a clear visor or face shield that covers the eyes, nose, and mouth, combined with a powered air purification system that supplies filtered air to the user. The main part of the respirator is reusable and therefore can reduce costs over time as only the filter would need replacing. They are generally more comfortable to wear for extended periods compared to traditional tight-fitting respirators.



Figure 6 - Powered visor respirator.

These types of respirators are generally more protective than non-powered half mask respirators as a fan pushes clean filtered air down the wearers faces, creating in effect a positive pressure inside the face piece under most work conditions, which reduces inward leakage of potentially contaminated air. It should be noted that the correct type of filter should be selected and fitted to suit the contaminant being filtered.

## The Health and Safety at Work etc. Act 1974

Given that the health and safety advice from SSERC is underpinned by various pieces of legislation, we thought it might be an idea to let you know a little about the Acts and Regulations that affect schools and colleges.

It is worth saying at the outset that health and safety is not a devolved matter: all health and safety laws are set in Westminster.

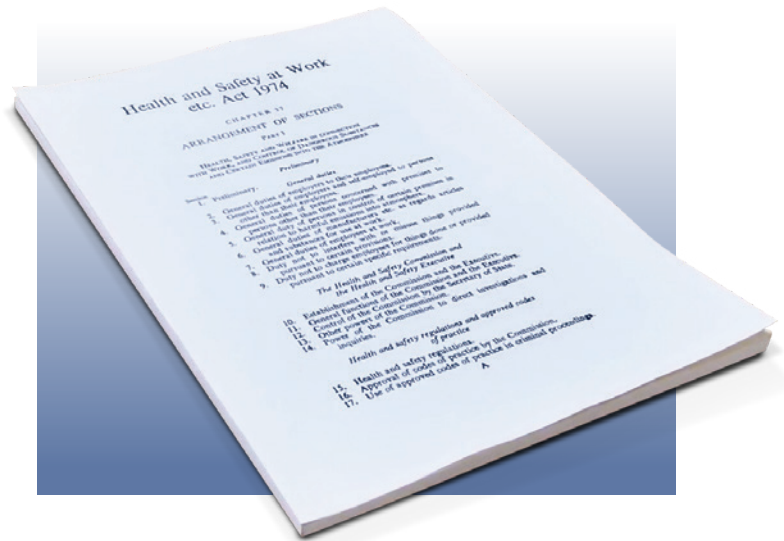
We'll start at the beginning. There is in fact only one Act directly relating to health and safety, The Health and Safety at Work etc. Act 1974 (HSWA). An Act is what is known as primary legislation: a motion is tabled in Parliament, debated and voted on just like most other pieces of legislation we are familiar with.

### What is the HSWA?

HSWA is a key piece of legislation covering all aspects of health, safety and welfare in the workplace. It is an 'enabling' act – which means that it allows various health and safety regulation (such as COSHH and The Electricity at Work Regulations) to be introduced without any need for the normal parliamentary process – which can be very time-consuming. (Parliament can, though, block any proposed regulations).

### At work

This is a key point. There is no need to risk assess your garage before carrying out any work on your car (though strangely HSWA itself does not insist on risk assessment). But similar work in a college workshop would need to be risk assessed. Most of the time it is clear what being 'at work' means but travel can be confusing. If you are travelling for work, on a trip, collecting equipment, moving between premises on a split site, then that is considered as being at work. But travelling to work from your home and back does not.



### The key points of the act are:

#### Duties of employers

Most duties are placed on employers: Local Authorities for most schools but Boards of Governors in most colleges or independent schools. They must:

- ensure, so far as is reasonably practicable the health, safety and welfare at work of all his employees (a similar duty applies towards others who are not employees e.g. learners);
- make sure your workplace and equipment is safe and without risks to the health of workers and anyone else;
- produce, and make available, a health and safety policy;
- explain how risks will be controlled and tell you who is responsible for this in a way you can understand;
- consult and work with you and your health and safety representatives (if there are any) in protecting everyone from harm in the workplace;
- give you the health and safety training you need to do your job free of charge;
- provide any equipment and protective clothing needed for the job and ensure it is properly looked after free of charge;
- provide adequate facilities for welfare eg toilets, washing facilities and drinking water.



# Health & Safety

## Duties of employees

Employees do not get off scot free here. Duties are placed on you as well. You must:

- look after your own health and safety as well as that of others;
- follow the training you have received when using any work items your employer has given you;
- take reasonable care of your own and other people's health and safety;
- co-operate with your employer on health and safety;
- tell someone (your employer, supervisor, or health and safety representative) if you think the work or inadequate precautions are putting anyone's health and safety at serious risk.

This phrase *so far as is reasonably practicable* (SFAIRP) is widely encountered in health and safety law. It means that the risk in a particular situation can be balanced against the time, trouble, cost and physical difficulty of taking measures to avoid the risk.

This is, in the end, a judgement. Guidance is available from the HSE but ultimately the decision about whether a measure is practicable is for the courts.

*E.g. providing a rubberized surface over a whole playground at the cost of £1,000,000 to prevent grazed knees is clearly not reasonably practicable.*

*Providing suitable ear defenders for workers in a noisy workshop, clearly is.*

One of the most important aspects of the Act is that it allows all sorts of other health and safety law to be passed in the form of secondary legislation which, to all intents and purposes, by-passes Parliament. We will look at the most important of these regulations in future Bulletins. <<