Bright and Brilliant

Light, colour and the nano world

Key Stage 4 Programme

Pupil Name	
Handbook Designed by	Dr L. Brooks

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
Lab visit			
6			
7–Conference			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline assessment: Poster presentation	
Tutorial 2	Scientific diagrams	
Tutorial 3	What's it all for?	
Tutorial 4	Literature Review	
Tutorial 5	Theoretical background	
Tutorial 6	Final assignment: Conference poster	

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

The Brilliant Club KS4 Programme – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at AS-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

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Course Rationale

Colour delights and fascinates, but it's also inextricably linked to some of the most far-reaching concepts in physics - the nature of light, and the properties of matter .

Bright and Brilliant takes you on a dazzling tour of the science behind colouration, delivered through a series of mini-lectures, demonstrations, and hands-on experiments.

Along the way, we'll be exploring some colourful conundrums, such as...

What is colour, and where does it come from?

What gives a peacock's tail its shimmery sheen?

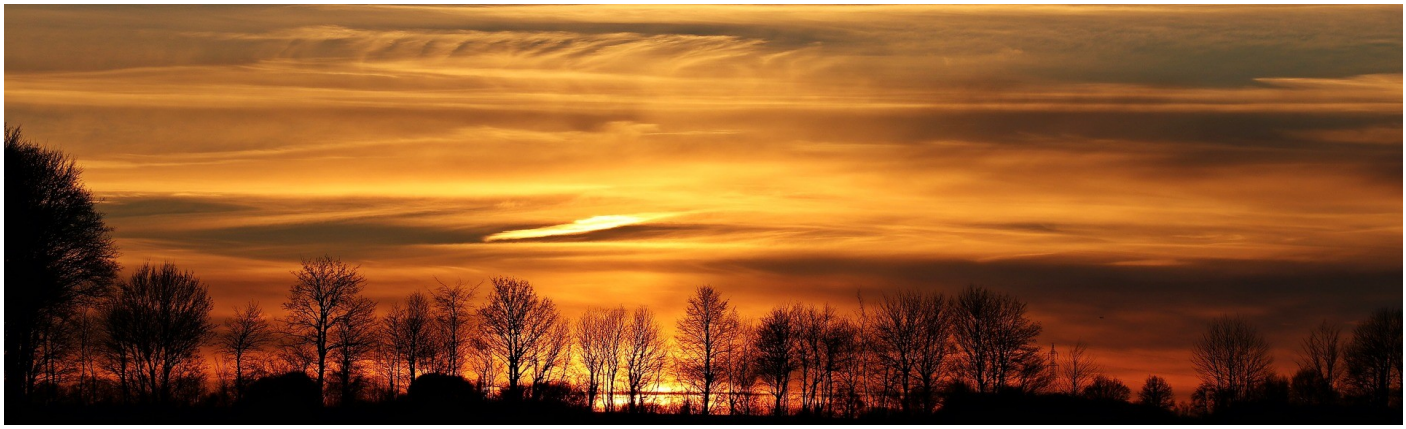
Why is the sky blue?

To find the answers, we'll need to zoom right in on matter at very tiny scales, and our investigations will lead us into the strange realm of nano-science. To find out more, you'll visit the laboratories of the NanoPhotonics Centre at the University of Cambridge, where you'll meet researchers at the cutting-edge of nano-science.

Throughout the course, you'll get a taste of what it is like to study physics at university level, and a glimpse into the world of research. Meanwhile, you'll also develop a raft of advanced scientific skills, including:

- How to take effective notes from a lecture
- How to pick apart and understand a scientific research paper
- How to plot and analyse experimental data
- How to present your findings at a scientific conference

Finally, to celebrate all your achievements, you will end the course by showcasing your work to family and friends at our Bright and Brilliant Conference 2018!



Whether we're watching a beautiful sunset, or just choosing a new t-shirt, most of us would agree that colour matters! But what is the science behind what we see?

Mark Scheme Table

	Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)
Subject knowledge	Knowledge and Understanding	• All content included is relevant to the general topic and to the specific question/title • Good understanding of all the relevant topics. • Scientific terms are defined and used accurately throughout • Clear justification of how the content included is related to the specific issues that are the focus of the assignment	• Most of the content included is relevant to the general topic and to the specific question/title • Good understanding of most the relevant topics • Scientific terms are used accurately but not always clearly defined. • Adequate justification of how the content included is related to the specific issues that are the focus of the assignment	• Some of the content included is relevant to the general topic and to the specific question/title • Good understanding on some of the relevant topics but occasional confusion on others. • Scientific terms are used mostly accurately with occasional confusion and often not defined. • Some justification on how the content included is related to the specific issues that are the focus of the assignment
Critical Thinking	Research and Evidence	• Inclusion of rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/ calculations to support claims/ assertions/ideas, consistently clearly and convincingly • Evidence of further reading beyond materials provided which were used in an appropriate context • Data is effectively analysed and appropriate assumptions/ conclusions are reached	• Inclusion of adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/calculations to support claims/assertions/ ideas, mostly clearly and convincingly • Evidence of further reading beyond materials provided • Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	• Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas • Use evidence/ calculations to support claims/ assertions/ideas, at times clearly and convincingly • Limited evidence of further reading beyond materials provided • There is an attempt to analyse data is and draw assumptions/ conclusions

Critical Thinking	Critical Evaluation	• Moved beyond description to an assessment of the value or significance of what is described • Evaluative points are consistently explicit/ systematic/ reasoned/justified • Effective critiques on the reliability of sources provided	• Mostly description but some assessment of the value or significance of what is described • Evaluative points are mostly explicit/ systematic/ reasoned/justified • Some evidence of critiques on the reliability of sources provided	• Only description with minimal assessment of the value or significance of what is described • Evaluative points are at times explicit/ systematic/ reasoned/justified • Limited evidence of critiques on the reliability of sources provided

Written Communication	Structure and Presentation	• Ideas are presented and arranged in a logical structure that is appropriate for the assignment • The introduction clearly outlines the work undertaken • The conclusion summarises all the main points clearly and concisely • All calculations, formulas and methods are clearly structured, clear to follow and correct • Tables and graphs are effectively constructed including appropriate headings, units and scales. • All sources are referenced correctly in an agreed format	• Ideas are presented and arranged in a structure that is mostly appropriate for the assignment • The introduction adequately describes the work undertaken • The conclusion summarises most of the main points clearly • Calculations, formulas and methods are mostly structured, clear to follow and correct • Most tables and graphs are well constructed • Most sources are referenced correctly in an agreed format	• Ideas are presented and arranged in a structure • The introduction mentions the work undertaken • The conclusion summarises some of the main points clearly • Calculations, formulas and methods are not always structured, clear to follow and correct. • Some tables and graphs are well constructed but contains some errors • Some sources are referenced correctly in the agreed format with occasional errors
	Language and Style	• No spelling, grammar or punctuation errors • Units and significant figures are presented accurately throughout • Writing style consistently clear, appropriate for scientific documents and easy to follow • Accurate and consistent use of technical language and vocabulary	• Minimal spelling, grammar or punctuation errors • Units and significant figures are presented accurately throughout • Writing style mostly clear, appropriate for scientific documents and easy to follow • Some attempts of using technical language and vocab alary, but not always accurate	• Some spelling, grammar or punctuation errors • Units and significant figures are presented accurately throughout with occasional errors • Writing style moderately clear, appropriate for scientific documents and easy to follow • Use of simple language and vocabulary effectively but struggles to use technical language

Glossary of Keywords

Word	Definition	In a sentence
Pigment	A compound that selectively absorbs certain wavelengths of light to produce colour.	Dyes contain pigments.
Wavelength		
Frequency		
Spectrum		
Spectroscopy		
Absorption		
Transmission		
Transmittance		
Scattering		
Constructive interference		
Destructive interference		
Structural colour		
Iridescence		

Glossary of Keywords

Word	Definition	In a sentence
Nanotechnology		
Nanoparticle		
Scientific paper		
Scientific journal		

Tutorial 1 – Chasing rainbows

What is colour, and where does it come from?

From Aristotle to Isaac Newton, this question has fascinated thinkers through the ages. What is more, the answers lead us right to the heart of some fundamental scientific theories...

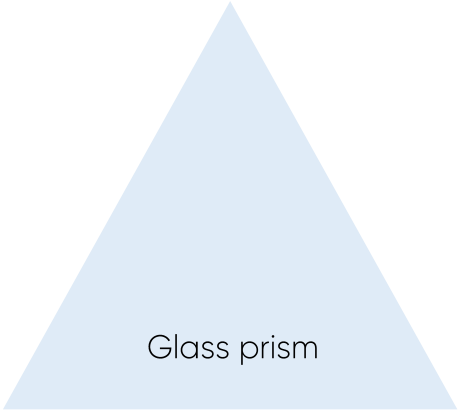
Prepare to be dazzled!

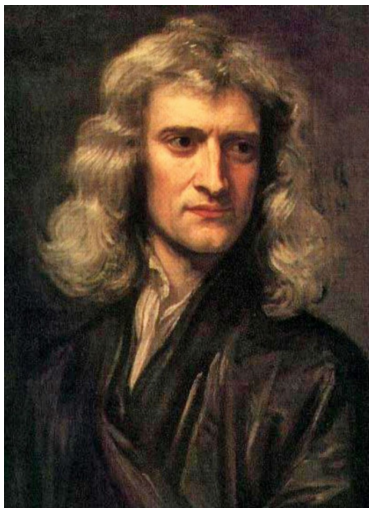
Objectives:

- Understand the relationship between light and colour
- Investigate various ways that colour is produced
- Develop good scientific record keeping
- Take effective notes from a university-style lecture

Light and colour

Complete the diagram...

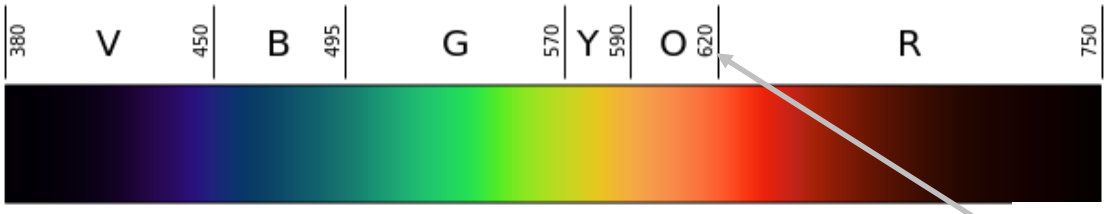




Portrait of physicist Sir Isaac Newton (1642-1727)

Newton's prism experiment

What does Newton's famous experiment tell us about the relationship between light and colour?



Q. What do these numbers represent? What are the units?

The spectrum of visible light

Investigation 1 – Building and testing a spectroscope

A spectroscope is an instrument that splits light into its component wavelengths. It does this using a device called a *diffraction grating.*

Spectroscopes allow us to analyse which wavelengths (colours) are present in the light we are detecting. This seemingly simple information can be really valuable, especially when we want to find out about something that we can't physically touch.

For example, scientists use spectroscopy to deduce what stars are made of, just by measuring the wavelengths of light they emit. Meanwhile, some cancer researchers use spectroscopy to get information about a patient's tumour, without needing to take a sample of tissue.

Scenario:

Your research team is out on field work, without access to all your usual laboratory equipment. Do you have the ingenuity to build your own spectroscope, using the simple resources you have to hand?

Once you have built your spectroscope, test it out by making some careful observations of a range of objects and light sources. What do you notice? What does this tell you about how colour arises?

Key skill focus:

Scientific record keeping

It is crucial for scientists to keep accurate and complete records of their investigations.

There are several reasons for this:

- So that measurements and other data can be used and analysed later on
- So that experiments can be repeated in the future or replicated by other scientists
- To help experimenters plan, carry out, and evaluate their work systematically and effectively
- To help experimenters interpret their results
- To prove who discovered something first, and to guard against false claims or fake data.

Top tips:

- Record what you are doing as you do it—not afterwards
- Notes should be legible and understandable to others—but they don't need to be neat!
- All work should be clearly dated
- Include all the details that someone else would need in order to repeat your work. Diagrams are often ideal.
- Include any tables or graphs of your results, or sketches of your observations. Don't forget units!
- Annotate your work to show what you are thinking as you progress through your investigation.
- Don't write over anything—cross through mistakes and re-write them.

Date:
Title: Spectroscope investigation

Discussion: Where does colour come from?

Collaborate with a colleague to discuss your findings.

Can you come up with a hypothesis that might explain your observations?

Hypothesis (noun)

Proposed explanation—a starting point for further investigation

Stretch and challenge

Can you think of a way to test your hypothesis?

Lecture 1: Where does colour come from?

Key skill focus:

Note-taking

Attending lectures is a really important part of studying at a university. A lecture is a talk given by a professor, often with hundreds of students in the audience. Listening actively and taking good notes are key study habits for university students.

Over the next tutorials, you will have lots of opportunities to practise and improve your note-taking skills...

Top tips:

- Don't write down every word—listen carefully and figure out what are the most important points
- Use bullet points and sketches to record information quickly
- Highlight and underline key points
- Make a note of any questions you have so you can ask the lecturer at the end

Homework 1: Poster presentation (Baseline assignment)

Date due:

Scientists communicate their work to other researchers at scientific conferences. They often prepare posters to use as visual aids that help them explain their research. These posters usually show diagrams of experimental set-ups, graphs of key results, and bullet points giving key information. They are designed to grab attention in a busy exhibition hall - text is best kept to a minimum!

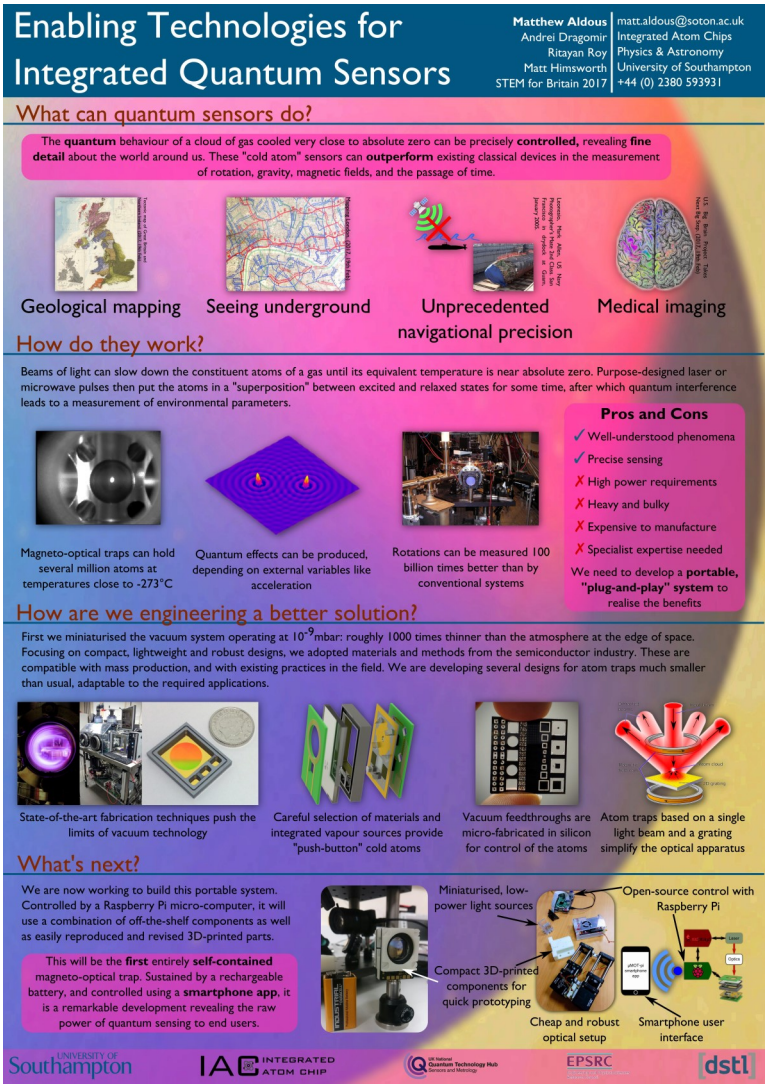
Your task:

Produce a scientific poster to present the findings of your spectroscope investigation.

Your poster should show the following information in a visual and eye-catching way:

- The aim of your investigation (what you wanted to find out)
- Your method (what you did)
- Your results (what you found out)
- Your conclusions (what you think it means)

Be prepared to present your findings to the rest of the group in the next tutorial!



An example of an effective scientific poster...

Tutorial 2 – Do or dye

Your favourite t-shirt, the ink in your pen, the colourful icing on a child's birthday cake—all of these things are coloured using dyes.

Dyes are liquids that contain chemicals called *pigments* that generate colouration.

In this week's tutorial, we will uncover the physics behind pigmentary colour, and you will use a spectrophotometer to measure the colour characteristics of some common dyes.

Objectives:

- Know that chemicals called pigments can produce colouration
- Describe and explain how optical spectroscopy works
- Carry out spectrophotometry measurements of coloured dyes

Poster presentation feedback

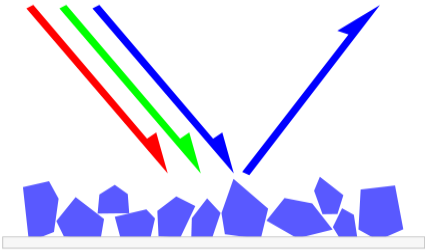
What went well:

Even better if:

Targets for improvement:

Student comments:

Lecture 2: Colour from pigments



Ultramarine blue pigment reflects blue light, but absorbs the other colours

Investigation 2 – Spectrophotometry

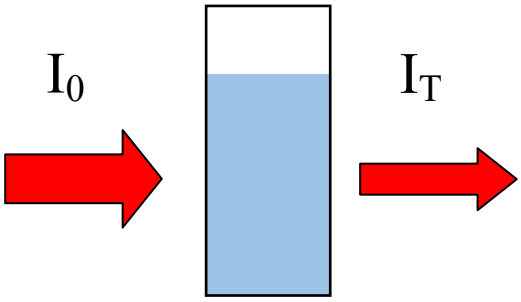
A spectrophotometer is a device that measures how much light is transmitted through a sample of fluid, for different wavelengths.

Unlike the spectroscope you built last week, this instrument gives us a *quantitative* measurement– the "transmittance" of the sample.

"Transmittance" is calculated from the intensity of the light that passes out of the sample, I_T, divided by the intensity of the light that was sent in, I_0.

Why do you think it is important to divide by I_0?

Spectrophotometers allows us to plot a transmission *spectrum* (a graph of transmittance vs wavelength) for our sample.



Cuvette

$$\text{Transmittance} = I_T \div I_0$$

Scenario:

You are a scientist working for a dye manufacturer. Your boss asks you to produce a technical data sheet for a new product. Can you measure the new dye's transmission spectrum so that your customers know what it is they are getting?

Lab notes

Homework 2: Scientific diagrams

Date due:

Clear diagrams are a key element of any research poster or report.

This week's homework gives you an opportunity to practise preparing top-quality scientific diagrams, ready for your final assignment.

Your task:

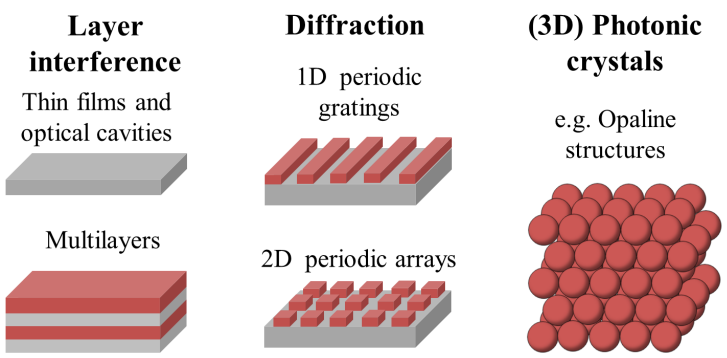
Use Powerpoint to create a diagram explaining the operation of a spectrophotometer.

Your diagram should:

- Be labelled
- Be clear
- Have a caption, explaining what is pictured, e.g. "*A digram showing…*"

Note: Remember that when it comes to diagrams, simpler=better., so there's no need to spend lots of time. Make a quick sketch on paper first, and think about how to draw it as simply as possible. Tips: in Powerpoint, use Insert->shapes to get a basic outline for your drawing. If you need to customise the shape , you can then right click on it and select 'edit points' to move parts of the shape around.

Remember—if your diagrams is good you can reuse it for your conference poster!



Examples of simple diagrams pro-duced using autoshapes.

Tutorial 3 – Riding the waves

By now we know that the wavelength of light is key to colour, but what about light's other wavy characteristics?

If you have ever stood on the sea shore watching the waves roll in, you might have noticed something interesting. When two or more waves meet at the same spot, they can either add together - to make an even higher wave—or they can act to cancel each other out.

This is the principle behind wave interference, and it happens with light waves too.

But what's interference got to do with colour?

This week we'll be finding out...

Objectives:

- Know that light can behave like a wave
- Understand optical interference and its role in colouration
- Be able to describe and explain examples of structural colour

How waves behave...

What I think I know already....

Constructive and destructive interference

Stretch and challenge

How might wave superposition and interference explain the iridescence of some butterfly wings?

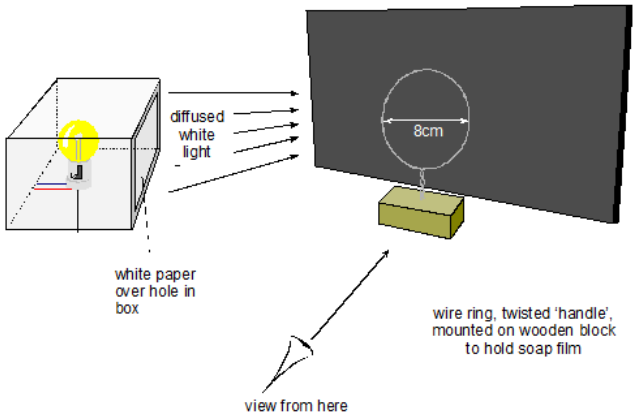
Lecture 3: Colour from structure

Investigation 3: Interference patterns in a soap film

The beautiful colours on a soap bubble result from the interference of light.

In today's investigation you will...

1. Observe the iridescent colouration of a soap bubble
2. Investigate what happens as the thickness of the soap film changes



Credit: Advancing Physics CD-ROM (2000)

Lab notes: Interference patterns in a soap film

Homework 3: What's it all for?

Date due:

Good scientific research usually takes a lot of time and effort, and can often be expensive too. Scientists need to be highly motivated in their work, and able to explain why their research is worthwhile. They also need to be fully aware of how their research is viewed in wider society, and what kind of impact their discoveries might have.

Your tasks:

This week's homework is in two parts...

Part 1. Mind map

Research and reflect on the various applications (uses) of light and colour in modern life.

Create a mind map illustrating the importance of colour. Use images, diagrams and text to present your thoughts.

Try to include as wide a range of ideas as possible.

For example, you might consider:

- Medical applications
- Fashion
- Display technologies
- Street lighting

... etc!

Part 2. Personal Reflection

Imagine you are awarded a grant (a sum of money) to spend on researching anything you wanted. What would you choose to investigate? What areas of science do you personally find interesting? What is important to you? What problems would you like to solve in the world?

Reflect and write a paragraph in response to these questions.

Tutorial 4 : The sky's the limit

Why is the sky blue?

And why are sunsets red?

This week we're aiming sky high as we explore how colouration can be caused by the scattering of light by tiny particles, such as the molecules in our atmosphere.

But we won't be spending all our time up in the clouds— we'll also be learning how the Romans used gold nanoparticles to produce beautifully coloured green and red glass, and how today's scientists are harnessing the peculiar properties of metal particles to make super-sensitive sensors!

Curious? Get ready for a particular-ly interesting tutorial...

Objectives:

- Know that tiny particles can produce colouration by scattering light
- Be able to explain why the sky is blue
- Know that gold nanoparticles do not look gold-coloured —they can be red, they can be green—in fact they can be a whole range of colours, depending on their size and shape!

Investigation 4: Why is the sky blue?

Lecture 4: Colour from particle scattering

Homework 4: Literature Review

Date due:

When scientists discover something interesting, they write a report about their work - called a 'paper'- and submit it to be published in a scientific journal.

Publishing research is really important for the progress of science. It allows other scientists to test and verify new results, and to build on each others' findings. After all, there is no use in discovering something, and then keeping it to yourself!

When a researcher begins a new project, they often start by reading lots of papers to find out what other scientists have already done, and what the current theories are.

The ability to read and understand research papers is therefore a key skill for any scientist or student, - but it can be a challenging task! Scientific papers are information-dense, and often contain highly technical language and terms that are often unfamiliar to non-expert readers.

Don't worry though—with a bit of practice and some top tips, you will soon be a pro!

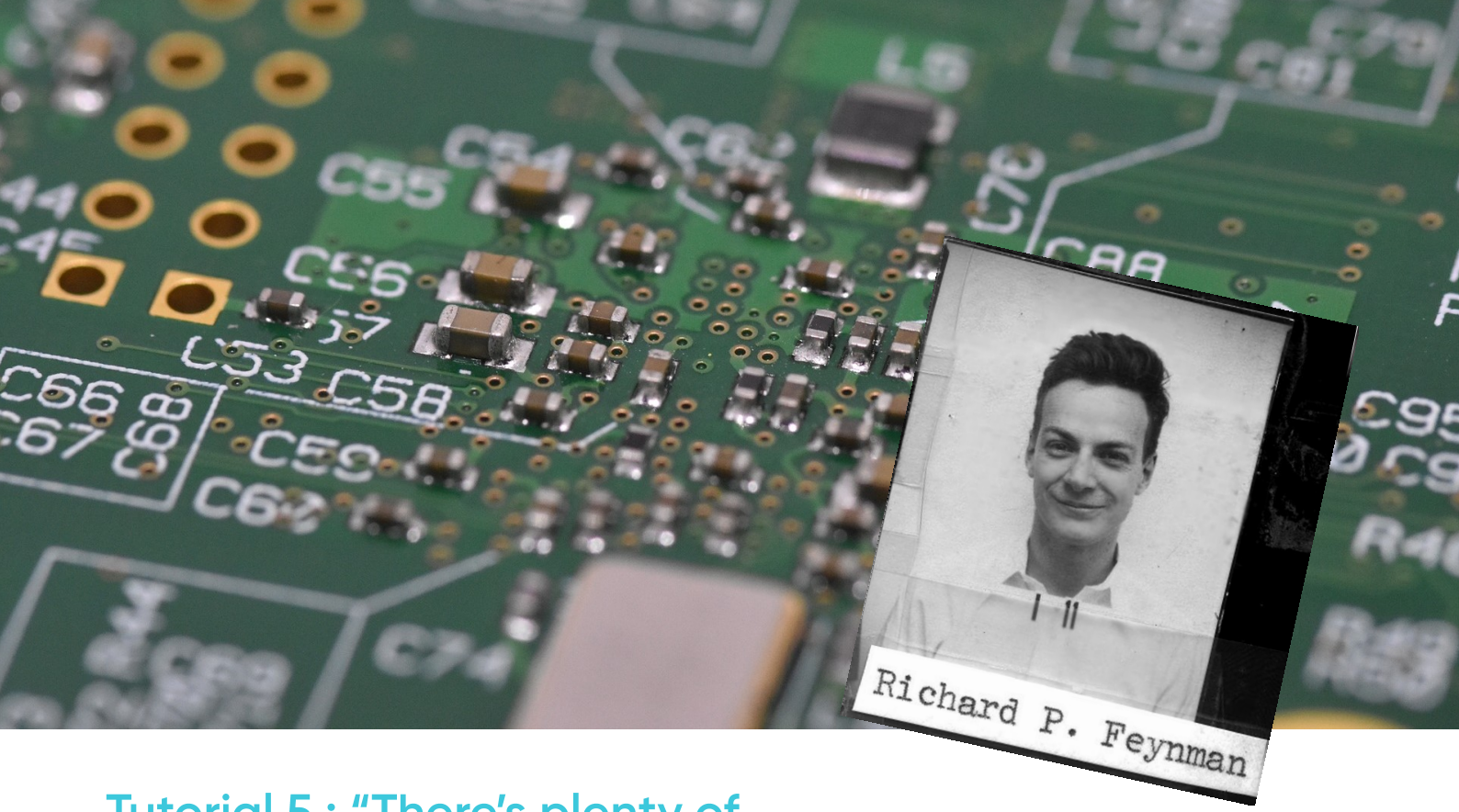
Top tips:

- Be patient! You won't understand everything the first time
- Read with a pen in your hand—highlight and write notes as you go along
- Circle key terms that you don't understand—then look up what they mean
- Try to answer: What is this paper about? What were the authors trying to find out? How did they do it? What did they find?

Your task:

Read the research paper extracts, highlighting key points as you go:

1. Create a list of 5-10 new key words that you come across. Use the internet or reference books to research what they mean, and write a definition in your own words. Important: Make sure you record the sources you use—(see Appendix 1).
2. Write a short summary (maximum 500 words) describing what you have understood from the papers, and from your wider reading.
3. Be prepared to discuss your findings with your colleagues in the next session!



Tutorial 5 : "There's plenty of room at the bottom"

"I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle…What I want to talk about is the problem of manipulating and controlling things on a small scale." - Richard Feynman, "There's plenty of room at the bottom".

The year was 1959. No one had yet set foot on the moon. Almost no-one owned a computer. Absolutely no-one had a Twitter account. But one man imagined a new field of science, one that could bring about enormous technological advances, one concerned with 'controlling things on a small scale'…

Today, we call this field **nanotechnology**.

Objectives:

- Know what is meant by the term 'nano scale'
- Be able to discuss the applications and implications of nanotechnology
- Give examples of equipment scientists use to make and study nano objects

Video– The strange new world of nano-science

https://www.youtube.com/watch?v=lKKpnpwwJTw

What is nanoscience?

How is it done?

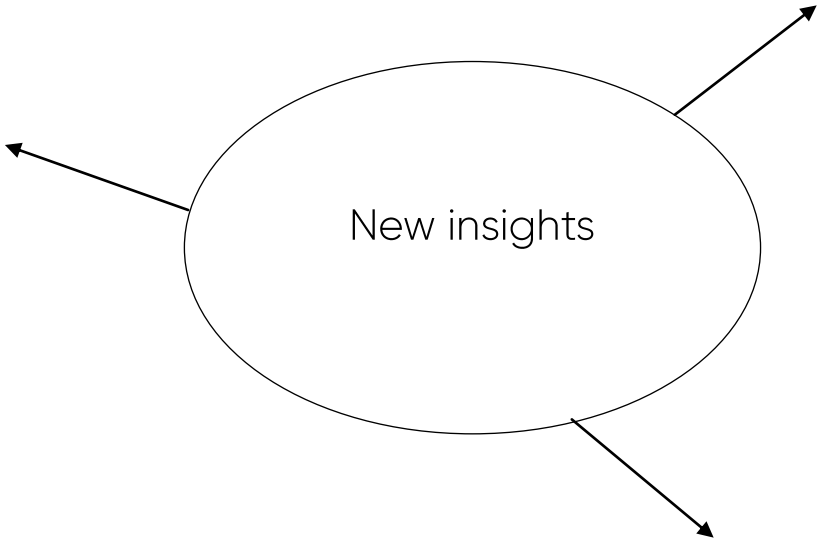
(techniques, equipment)

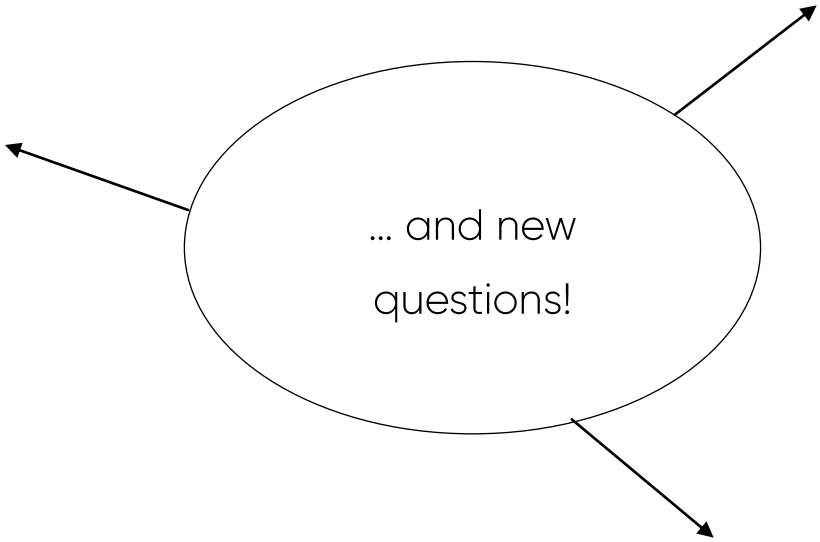
What can it do?

(applications, technologies)

What about the future?

Literature review: Share your findings...





"The important thing is not to stop questioning," – Albert Einstein

Homework 5: Theoretical background

Date due:

When researchers embark on a new project, it's important for them to understand the scientific theories that their work will build on. At university, students are often asked to write a preliminary report before they carry out an investigation. This report usually contains a 'background' section that explains the relevant physics. Here's your chance to try it out for yourself!

Your task:

Produce a set of Powerpoint slides explaining the following concepts:

1. Colour from pigments
2. Colour from structure
3. Colour from particle scattering

You should prepare one slide per topic (i.e. 3 slides in total).

Tips:

- Use clear, labelled diagrams (see Homework 2 for tips!)
- Keep your explanations succinct (short and to the point)
- Use correct scientific vocabulary

Remember, these diagrams can also be used for your final poster!

Lab visit: NanoPhotonics Centre, University of Cambridge

Now you know the basics, it's time to meet with some nano researchers to find out more!

Objectives:

- Visit a working nanoscience/photonics laboratory
- Meet with researchers in nanophotonics
- Collect data for your project.

Site and safety information

Lab notes

Lab notes

Lab notes

Tutorial 6 – Analysing and presenting data

Congratulations!

After weeks of hard work on your research project, you've been selected to present your findings at the Bright and Brilliant 2018 Conference.

Conferences are an opportunity to discuss your work with other scientists, to share ideas, to get feedback, and to find out what other researchers are investigating.

In today's tutorial, we will spend some time getting you all ready for your poster presentation. As well as plotting, analysing and interpreting your latest data, you will learn how to prepare a high quality scientific poster—and how to present it effectively!

Objectives:

- Be able to plot and interpret your experimental data
- Learn how to present your research at a scientific conference

Workshop:

How to present an award-winning poster

Lab notes

Final Assignment

Date due:

Resources:

Powerpoint template
Poster examples: http://www.setforbritain.org.uk/2017winners.asp
Your previous homework assignments

Your task:

Prepare and present a research poster to share your work with other scientists.

Your poster should include:

- Title
- Author name and affiliation,
  e.g. A. Person, Harris City Academy Crystal Palace
- Abstract
- Background physics
- Results (data, images)
- Discussion/conclusion
- References

Final tip:

Remember that your poster is a visual aid to attract attention and help you present your work:

Do include diagrams, graphs and photos,
Do keep text to a minimum.,
Do use titles, labels and bullet points to convey information,
Don't include long blocks of text.

Good luck!

Tutorial 7

Bright and Brilliant Conference 2018

Attach your conference itinerary here

Final Assignment Feedback

Final assignment feedback

What I did well...	What I could have improved on...

My target for future work is...

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?

What did you find challenging about the programme?	How did you overcome these challenges?

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

It gives credit to the authors of any sources you have referred to or been influenced by.
It supports the arguments you make in your assignments.
It demonstrates the variety of sources you have used.
It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

Quote directly from another source.
Summarise or rephrase another piece of work.
Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment:** After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].

2. **Bibliography:** This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

Websites – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

Books – Author, date published, title of book (in italics), pages where the information came from.

E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

Articles – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details:

You are able log into the VLE either through the link on our website (www.thebrilliantclub.org) or going directly to the VLE site at (https://portal.thebrilliantclub.org/sign-in).

- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames

If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: schools@thebrilliantclub.org)

What is the VLE?

The VLE is a virtual learning environment for all pupils on Uni Pathways it is used for:

messaging your tutor

submitting homework

submitting your final assignment

accessing resources for your tutorials

finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

Ensure you keep a professional tone in the messages you send to your tutors.

Ensure you always reply to your tutors in a timely manner.

Thank your tutor for the effort they are putting in to give you your feedback etc.

Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the 'My Activities' tab and not as an attachment to a message.

Notes

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