Shining light on reality, from the macro to the micro and the nanoworld

Key Stage 4 Programme – 2016-2017

Teacher : Stefano Boseggia

Pupil: _____

Timetable and Assignment Submission

Fill this in with your teacher.

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after 4.00pm on	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

KS4 Programme 2016-17 – 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 A-Level
2:2	50-59	Performing to an excellent standard at current key stage
3rd	40-49	Performing to a good standard at current key stage
Working towards a pass	0-39	Performing below a good standard at current key stage
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

Name of RIS Teacher			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		**FINAL MARK / 100**	
DEDUCTED MARKS		**FINAL GRADE**	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Learning Feedback Comment 1 - *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority	**How you could improve in the future**
Learning Feedback Comment 2 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority	**How you could improve in the future**
Learning Feedback Comment 3 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority	**How you could improve in the future**
Resilience Comment	
How you showed learning resilience during the course	**How you could build learning resilience in the future**

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Course Rationale

Living in a society that is becoming progressively more image and visual based means that our sight is becoming the most important sense. In order to visualize the world around us, our eyes collect the electromagnetic radiation deviated by any object and our brain processes it. It is fascinating to observe that often macro and micro cosmos are deeply related, thus, along similar lines, we can investigate the structure of very small objects.

Light, or electromagnetic radiation, travels in space like a wave. In this course we will discuss the most important properties of light and see how we can use them to investigate the structure of very small objects (about the size of a human hair). We will understand the pioneering work done by Young in the 19th century with practical activities and developing a simple theory. This will also allow us to learn how these principles are used in modern spectrometers to analyse the radiation coming from distant stars.

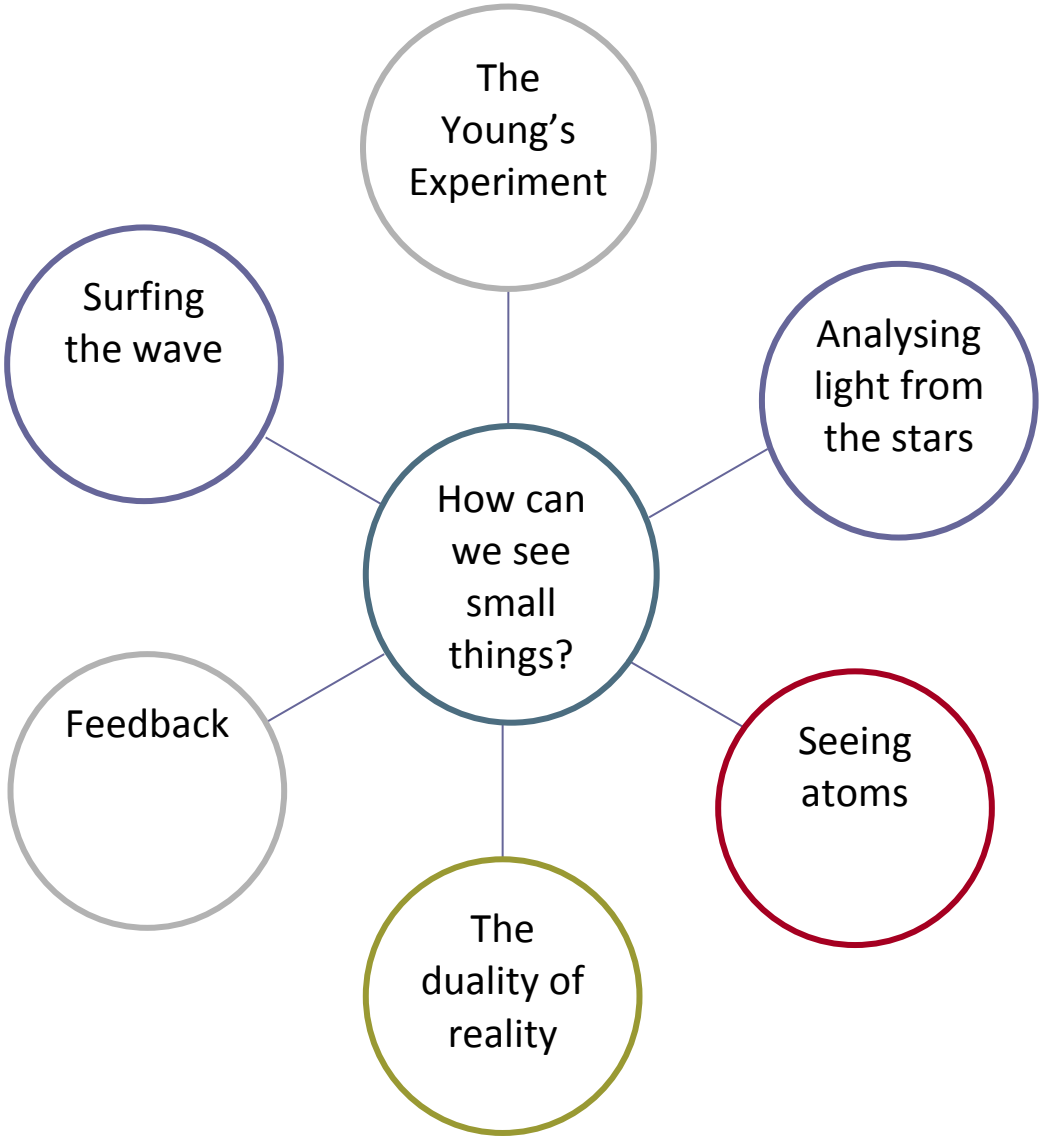
A very import prerequisite of building new material in modern technology is the control of the atoms position in the new engineered material. During this course we derive the famous Bragg Law and understand how to use it to determine the exact position of atoms within a crystal.

In the last part of the course we will briefly discuss an alternative way of describing the light, i.e. the particle nature of the electromagnetic radiation. We will understand that everything can be described both as a particle and as a wave. This approach can be extended to any real object too.

The course will strengthen skills of critical thinking and evaluation, which are essential in deciding which techniques is the most appropriate to investigate reality. We will also focus on applying mathematics and physics to unfamiliar problems, using basic mathematics and physics to evaluate the wavelength of different light sources or to determine the microscopical structure of infinitesimal small objects that are very important for science and in everyday life.

The final assignment will reflect the combination of these skills with a numerical/mathematical component requiring students to apply mathematics to significant optical set up, data of x-ray diffraction experiment, and an essay questions on the significance of a specific discovery. The final assignment will reinforce pupils' computer skills, making use of software for data analysis. A certain degree of creativity and imagination is required to answer challenging parts of some questions.

Course Map


The Young's Experiment
Surfing the wave
Analysing light from the stars
How can we see small things?
Feedback
Seeing atoms
The duality of reality

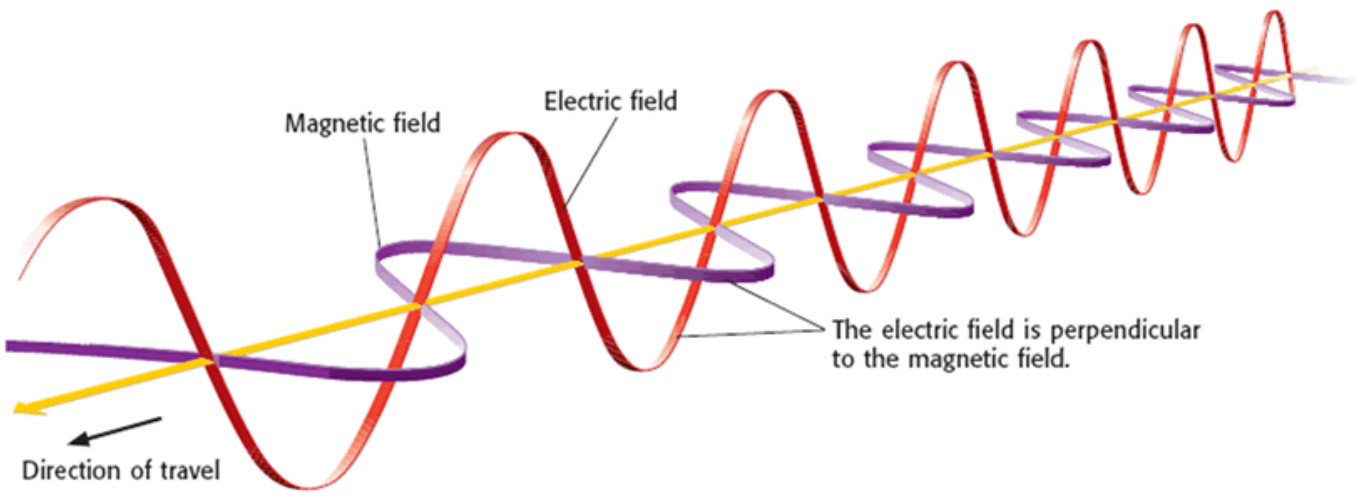
Mark Scheme

Key Skill	1st	2.2
Communication and language	☐ Writing is coherent an organized following a logical sequence. ☐ Writing is of an appropriate style for the scientific document and follows stylistic techniques ☐ Uses appropriate new and scientific vocabulary (phase difference, path difference, coherence, spectrometer, diffraction, interference, etc.) correctly and effectively.	☐ As time the writing is poorly organized with a lack of coherent structure. ☐ Inconsistent use of style throughout resulting in lack of clarity. ☐ Uses simple new vocabulary effectively but struggles with new vocabulary that is more challenging.
Contextualising	☐ Current theories or work in the field (interference, diffraction, particle-wave duality and photoelectric effect) are outlined making it clear how the assignment material fits into that context. ☐ Explains clearly why the topic is significant and worthy of discussion or investigation. He is able to foresee future applications and developments of cases studied. ☐ Context and significance are explored through comprehensive use of current literature.	☐ Little reference is made to current theories or work in the field, it is not clear how the assignment material fits into that context. ☐ Attempts but not clear discussion of why the topic is significant and worthy of discussion. ☐ 'Worthiness of investigation' is only covered from a personal motivation point of view.
Numerical Analysis	☐ All calculation clearly structure, clear to follow and correct. ☐ Confidently uses a wide range of formulae simultaneously (especially trigonometry), can choose the correct formulae and follow a structured method. ☐ Confident to interpret unseen numerical results to inform a physical meaning. ☐ Confident to use multiples or submultiples of units.	☐ Calculation structures are not always easily followed and contain mistakes in places. ☐ Uses formulae with success although at time it is unclear why particular formulae have been chosen. ☐ Uses simple formulae with confidence, at times struggles with complex methods within calculations. ☐ Attempts to infer physical meaning of results. ☐ Attempts to use multiple or submultiples of units with minor mistakes.
Application	☐ Make links between subjects that have not previously been associated. ☐ Uses concepts from the tutorial in an unfamiliar context, and does so accurately and confidently. ☐ Avoids the use of irrelevant data, arguments or knowledge.	☐ Needs direction to spot links between areas that have not previously been associated. ☐ When directed, applies concepts from tutorial to unfamiliar situation, reasonably and accurately. ☐ Confidently uses the concepts from their current key stage, but struggles with new concepts introduced in the tutorials that are at the key stage above current level.
Presentation of data	☐ Effective and sufficient mathematical skills have been used to process data allowing graph plotting. ☐ Uses the appropriate software for graph plotting in an effective and precise way. ☐ Uses the appropriate software to create publication quality figures.	☐ If complex calculations are necessary before constructing the graph, these may contain mistakes. This will lead to errors in graph plotting. ☐ Use the appropriate software for graph plotting with difficulties. ☐ Uses the appropriate software to create very simple figures.

Glossary of Keywords

Word	Definition	In a sentence…
Wavelength		
Frequency		
Period		
Interference		
Coherence		
Superposition		
Path difference		
Phase difference		
Diffraction		
Diffraction grating		
Laser		
Spectrometer		

Tutorial 1 – Surfing the wave



Today's Key Question(s):

- What is the frequency of a wave? What is the wavelength?
- How frequency and wavelength are related?
- What happens when two waves meet?

What is the Purpose of Tutorial 1?

- Introduction to the course
- Review of prior knowledge of waves
- New concepts in waves: superposition, phase difference and path difference

Activity 1– Units of length for the small world, high frequency

Activity 2– Waves, frequency, wavelength, amplitude and EM spectrum

Activity 3– Waves, reflection, refraction and diffraction

Activity 4– New concepts in waves: superposition, coherence, path difference and interference.

Today's Homework is:

- Baseline Assessment

Homework 1 – Baseline Test

The homework assignment for the first tutorial is a baseline test to see your initial level of attainment in this subject area. The assignment will test for some or all of the subject specific skills that are required later in the final assignment. However, it is shorter than the final assignment and is will be an introduction to the subject as well as a challenge!

Do not worry too much about doing 'well' or 'badly' on the baseline test, it takes into account the fact that you may not be familiar with the subject area. It is designed to help you and your PhD tutor identify where you are at the start of the programme and to help you measure your progress along the way.

1. Describe what a wave is. Can you give any example of waves in nature? (100 words)

2. Explain what is the difference between a transverse and a longitudinal wave? Can you provide some example of transverse and longitudinal waves? (Tips: Use appropriated diagrams to show what is the direction of propagation and the direction of the oscillation) (100 words)

3. Annotate in the table provided (Table 1) the different type of electromagnetic radiation, the associated wavelength and frequency. Try to investigate the relation between wavelength and frequency for each wave type. (Tip: there is a constant that connect this two quantities, can you identify which one?) Choose a type of electromagnetic radiation and research in the literature how it is produced and which are the most relevant applications (200 words). You should reference your sources (see Appendix 1).

4. In the SI system certain multiples or submultiples of units are preferred, e.g. kilometre= 10^3 m. Since the electromagnetic spectrum is broad, it can be useful to apply these prefixes to the wavelength. Look in the literature the meaning and the magnitude of the following multiples or submultiples of the meter and associate them to the different type of electromagnetic radiation:

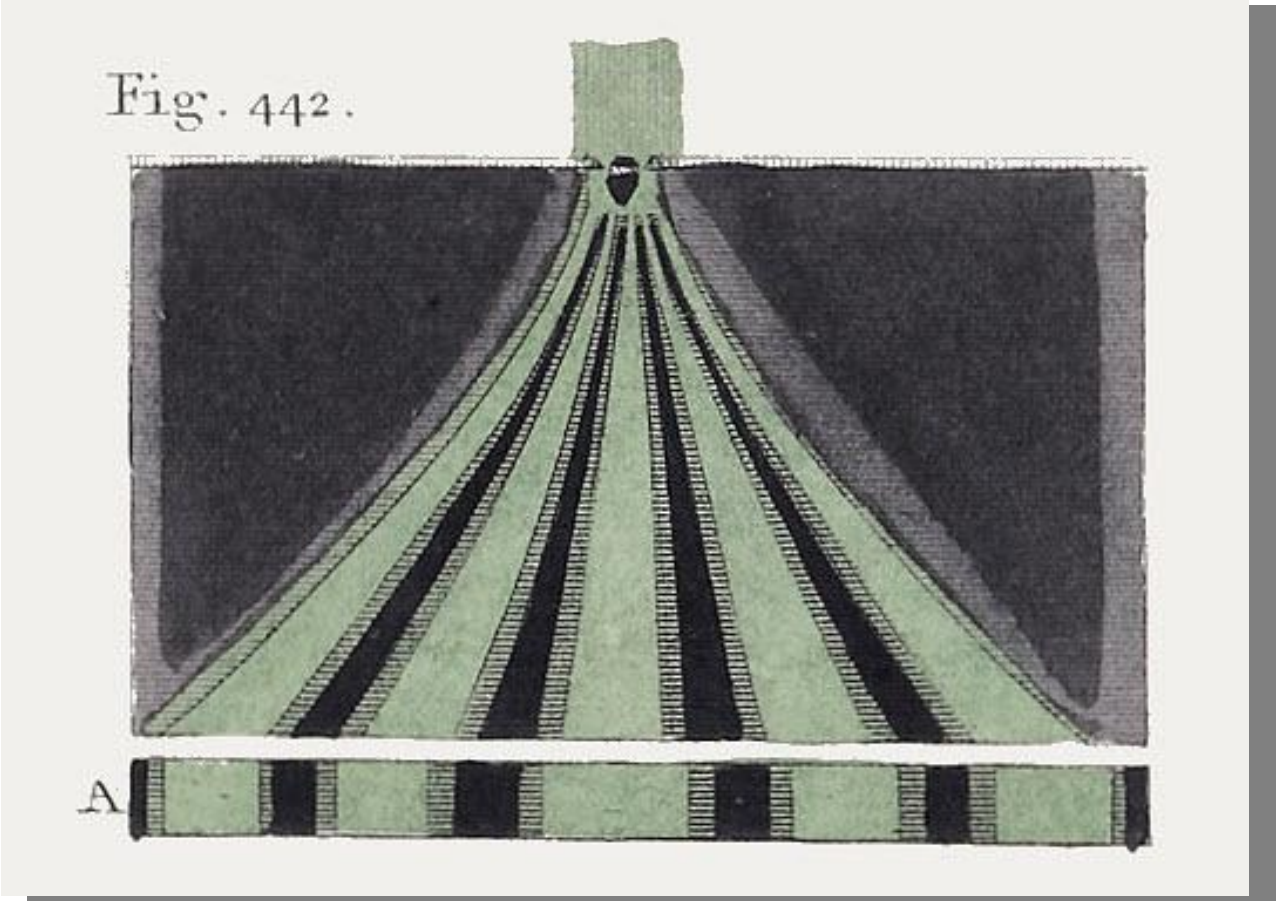
- picometre, pm
- Angstrom, Å
- nanometre, nm
- micrometre, µm
- millimetre, mm
- metre, m
- kilometre, km

Table 1 : Wavelengths and frequencies for the electromagnetic spectrum

Radiation	Wavelength (m)	Frequency (Hz)
Radio waves		
Micro waves		
Infrared		

Visible light		
UV light		
X-rays		
Gamma rays		

Tutorial 2 – The Young's Experiment



Today's Key Question(s):

- What happens when light passes through two small apertures?
- What changes in the interference pattern if the wavelength is changed?

What is the Purpose of Tutorial 2?

- Student presentation of some questions extracted from the baseline assessment and discussion.
- Quick review of the main concepts of Tutorial 1
- Understand how Interference of light and the famous Young's experiment work

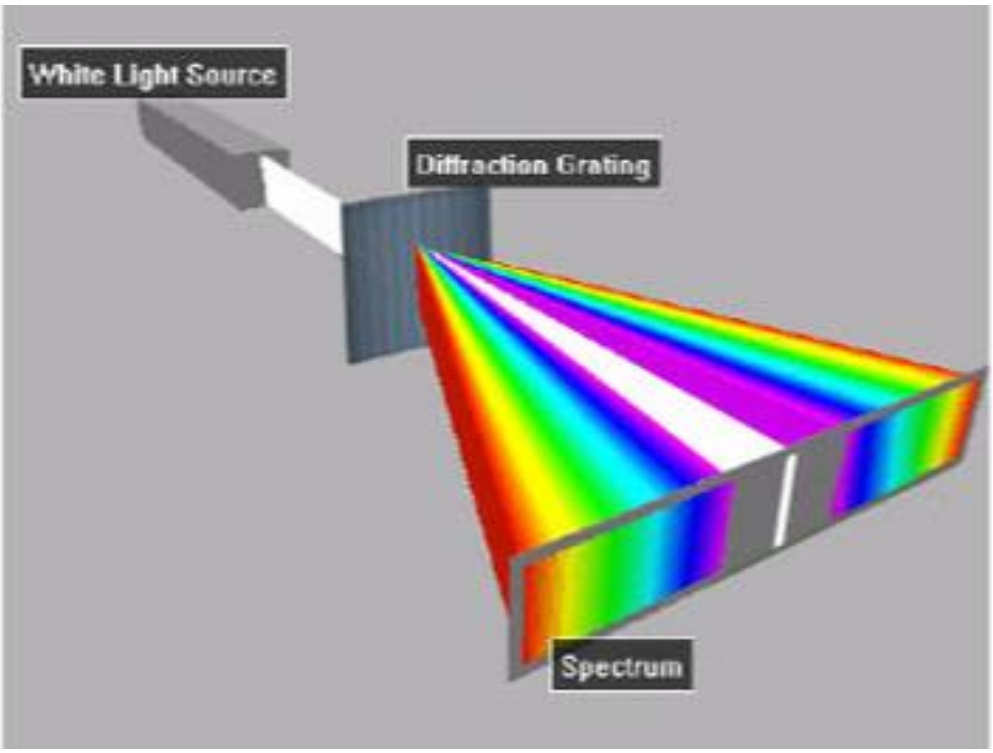
Activity 1– Learn what happen when light passes from two small apertures: the famous Young's experiment (demo)

Activity 2– Determine the position of the maxima in the interference pattern (problem set) and investigate the relationship between wavelength and maxima's position

Today's Homework is:

- Graphic questions on superposition of waves. Use of Excel to practice on superposition.
- Problem sets on various configurations of the double-slit experiment

Tutorial 3 – Analysing light from the stars: a diffraction based spectrometer



Today's Key Question(s):

- How can we determine the wavelength of a light source?
- What is the difference in the spectrum observed for monochromatic light and white light?
- How does a spectrometer work?

What is the Purpose of Tutorial 3?

- Review of the main concepts of Tutorial 2.
- Understand how a diffraction grating works.
- Understand how diffraction from a single aperture works.

Activity 1– Learn how to determine the wavelength of light or the grating spacing. Demo and problem set

Activity 2– Link between diffraction grating and a spectrometer. Building a spectrometer

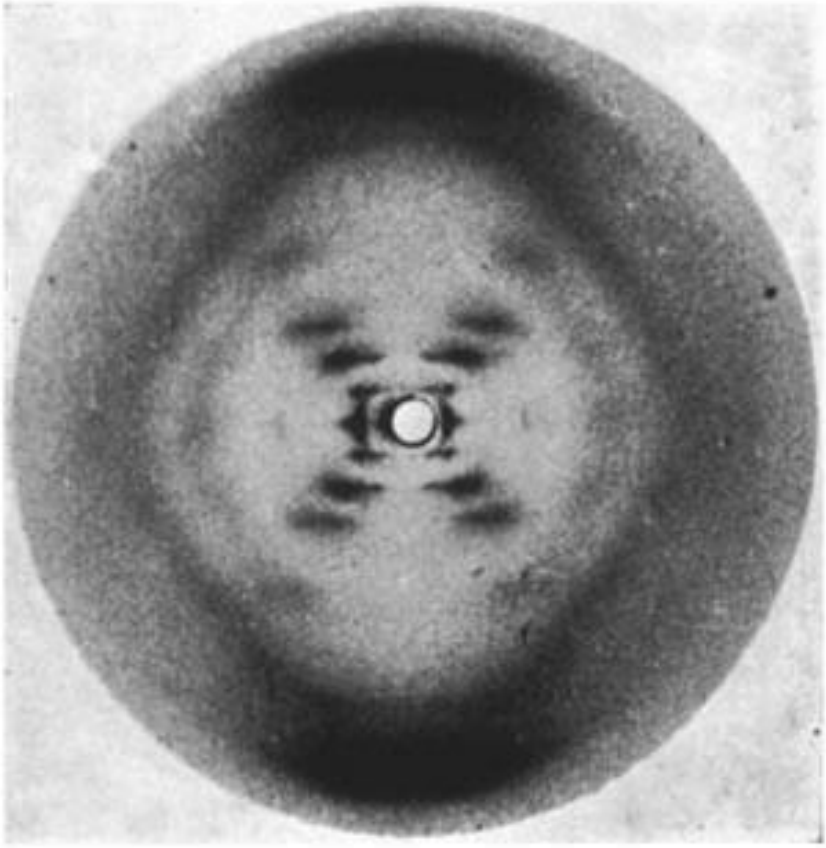
Activity 3– Learn what happen when light passes from a small aperture (demo)

Activity 4– Determine the position of the minima in the diffraction pattern (problem set)

Today's Homework is:

- Problem sets on diffraction gratings.
- Problem sets on diffraction from a single slit. Try to deduce the path difference of light that is reflected by two parallel layers.
- Look for picture provided on the internet (You can scan the picture with an app such as "Google Goggle"). Write 200 words about who obtain that picture, the technique they used and the general context of that research.

Tutorial 4 – Seeing atoms: the Bragg law



Today's Key Question(s):

- How can we determine the atomic positions?
- What changes in the diffraction spectrum as a function of the interatomic distances?

What is the Purpose of Tutorial 4?

- Learn how we can investigate smaller object: the positions of atoms.
- Understand how Bragg diffraction works, qualitative and quantitative

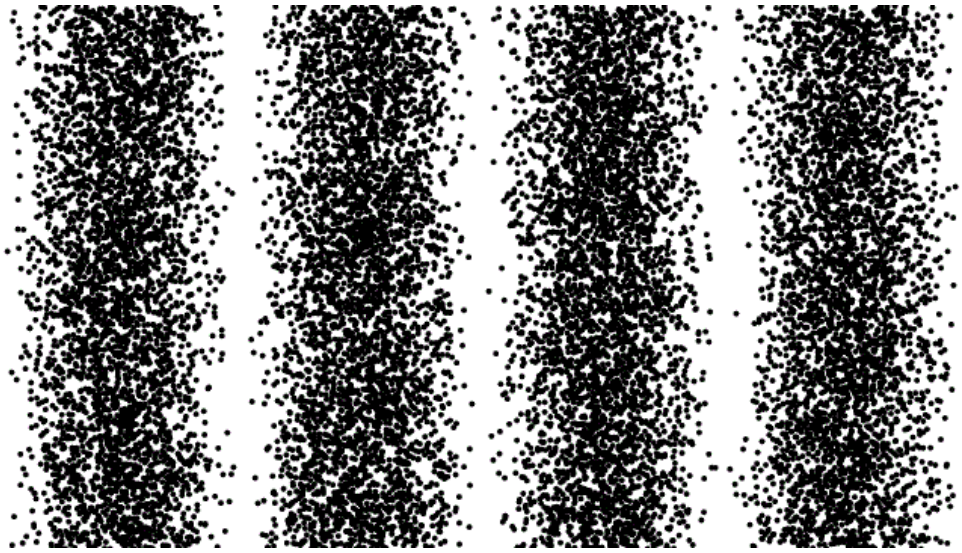
Activity 1 – Use of Bragg equation to calculate atomic distances.

Activity 2 – Replicate the Rosalind Franklin experiment on DNA (demo)

Today's Homework is:

- Draft Final Assignment

Tutorial 5 – The duality of reality



Today's Key Question(s):

- Which experiment demonstrates that light can be described as a particle?
- What is the wavelength of an electron travelling at a specific speed?
- Can we use other particles than light to study the materials' structure?

What is the Purpose of Tutorial 5?

- Discuss the draft of the final assignment.
- Understand the particle-wave duality of light.
- Learn what is the most famous proof that light behaves like a particle
- Learn that all matter can me describe like a wave

Activity 1: Light can be described as a particle: the photoelectric effect (demo and theory)

Activity 2: Electrons and massive particle can be described as wave (theory)

Activity 3: The De Broglie equation and the wavelength of an electron (theory, problem set)

Today's Homework is:

- Final Assignment

The Deadline is:

Homework – Final Assignment

For your final assignment please answer the following questions in a structured manner, using as much of the scientific language you have learned from the previous tutorials. Use of appropriate schematic is suggested to help you describe particular geometrical set up. Where mathematical calculation is required remember to include all your working and make use of the proper physical units. All answers will be checked for plagiarism so think about it yourselves and use the knowledge you have gained to the best of your ability without copying and pasting from Wikipedia, etc.

Question 1

Describe (with the help of a schematic, if appropriate) the Young's double slit- experiment. Discuss its implications for our understanding of the physical world? (300 words)

Question 2

Problem set: laser wavelength and diffraction grating. Describe how a diffraction grating can be used as a spectrometer and how a spectrometer works (200 words).

Question 3

Problem set: determine the position of the minima in a diffraction experiment.

Question 4

Describe how Bragg diffraction works (200 words). Derive the Bragg law with the help of a drawing of the diffraction process. Problem set: a diffraction spectrum as a function of temperature is given. You have to use Excel to create a graph (spacing vs angles). Deduce what happens to the crystal as a consequence of the change in temperature?

Question 5

Calculate the wavelength of a tennis ball travelling at a specific speed. Why we do not observe any diffraction but the ball travels along a straight path?

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

- Reflect on skills learned on the programme with a view to encouraging resilience
- Receive feedback on final assignment

What are the key questions?

- What strengths have I demonstrated in my work and what areas of development are there left for me to address?
- What steps do I need to take to improve my academic output?

Activity 1 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.

2.

3.

What could be improved?

1.

2.

3.

Activity 2 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

Activity 3 – Looking Forwards: Think, Pair Share

1. Think about how you can use this feedback in your future school work.
2. Talk to your partner about how you both plan to make changes to your school work in the future as result of this feedback
3. Share your ideas as a group.

You may choose to keep/delete this Appendix: 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:

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].

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 – University Applications Guidance

For course choices and careers information:	www.brightknowledge.org.uk
For information and statistics on universities and course:	www.unistats.direct.gov.uk
For comprehensive information on universities, including rankings:	www.thecompleteuniversityguide.co.uk

PLEASE NOTE – The Researchers in Schools programme is designed to support the university applications process at your school. The work you complete for the programme should add to your schoolwork rather than detract from it. Please be aware of deadlines and try to manage your workload appropriately. If you are worried about the programme interfering with your schoolwork then please speak to your teacher.

Subject Specific Top Tips for Strengthening an application?

What ideas do you have for how students can prepare for university in your subject area or related discipline? Share top tips, reading lists, events, films, videos or podcasts that you think could help your students to succeed.

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