The Absence Of Light

Key Stage 4 Programme

Pupil Name	Name
Handbook Designed by	Dr. J Rigueur

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Launch Trip)			
2			
3			
4			
5			
6 (Feedback)			

Timetable – Homework Assignments

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

Assignment Submission – Lateness and Plagiarism

Lateness	
Late Submissions	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 A-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

Name of PhD Tutor			
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 PhD tutor 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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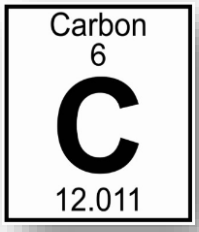
Course Rationale

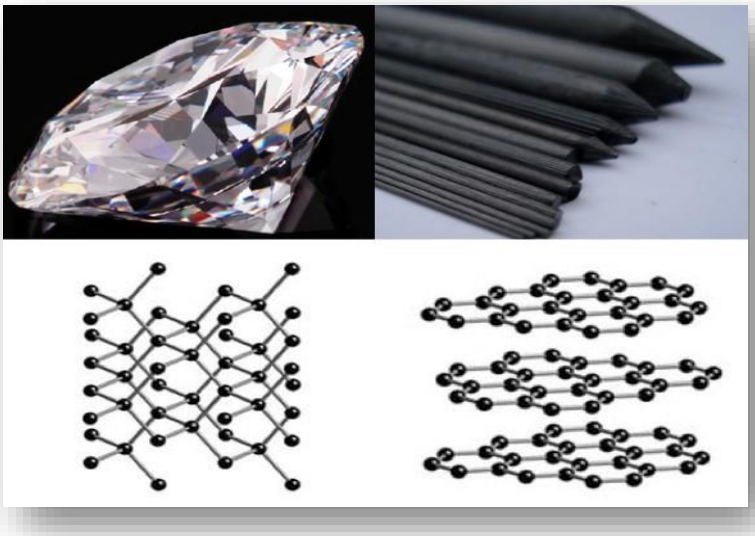
Carbon is an interesting material; in fact it is the basis of life on earth. Moreover, it is one of the most investigated materials in nanotechnology due to its many forms. These many forms of the element carbon are referred to as allotropes. For example, diamond, graphite and amorphous carbon (coal) are all allotropes of carbon. Current technology is based on silicon, however carbon has ushered in a new era and will provide technological leaps forward.



This course will commence by looking at the allotropes of carbon on the nanoscale and their varying dimensionalities. This dimensionality produces interesting phenomena that are of high interest for novel applications in physics and nanotechnology. What is even more interesting is what happens when light interacts with the varying dimensions.

For the remaining tutorials we will focus on how we can manipulate this unique dimension to create the absence of light. What do you mean by, "Absence of light"? This term refers to an object that absorbs all light by not allowing it to escape. The only natural object that can do this is a black hole. Thus we will focus on how a material made of carbon can achieve the same function.

To conclude this course students will work on a final project where they will give a 10-15 minute presentation. This will build confidence in presenting and allow students to be able to hold a scientific conversation explaining why carbon is so diverse and what other advances could be developed. They will be able to understand theoretically a concept that is still being investigated but has numerous applications and benefits for their lives.



Diamond and graphite are both made from the same element, carbon! They are allotropes of carbon and have different properties.

<u>Question:</u>

What do you think these different properties are?

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 on 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 on 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.	○ 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.	○ 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.
	Developing an Argument	○ Argument/proof exceptionally well-developed and well-justified ○ Makes links effectively between subjects that have not previously been	○ Argument/proof clear and well-developed and position justified ○ Some evidence of linking subjects that have not previously been associated ○ Use some	○ Argument/proof clear but not well-developed ○ Limited evidence of linking subjects that have not previously been associated ○ Limited use of concepts from the

		associated o Uses concepts from the tutorials in an unfamiliar context, and does so accurately and confidently. o	concepts from the tutorials in an unfamiliar context, but not always accurate.	tutorials in other contexts.
	Critical Evaluation	o Moved beyond description to an assessment of the value or significance of what is described o Evaluative points are consistently explicit/systematic/reasoned/justified o Effective critiques on the reliability of sources provided.	o Mostly description but some assessment of the value or significance of what is described o Evaluative points are mostly explicit/systematic/reasoned/justified o Some evidence of critiques on the reliability of sources provided.	o Only description with minimal assessment of the value or significance of what is described o Evaluative points are at times explicit/systematic/reasoned/justified o Limited evidence of critiques on the reliability of sources provided.
Written communication	Structure and Presentation	o Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment o The introduction clearly outlines how the presentation will deal with the question o The conclusion summarises all the main points clearly and concisely o All sources are referenced correctly in an agreed format.	o Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment o The introduction adequately describes how the presentation will deal with the question o The conclusion summarises most of the main points clearly o Most sources are referenced correctly in an agreed format.	o Ideas are presented in paragraphs and arranged in a structure o The introduction mentions how the presentation will deal with the question o The conclusion summarises some of the main points clearly o Some sources are referenced correctly in the agreed format with occasional errors.
	Language and Style	o No spelling, grammar or punctuation errors o Writing style consistently clear, appropriate for scientific documents and easy to follow o Accurate and consistent use of technical language and vocabulary	o Minimal spelling, grammar or punctuation errors o Writing style mostly clear, appropriate for scientific documents and easy to follow o Some attempts of using technical language and vocab alary, but not always accurate	o Some spelling, grammar or punctuation errors o Writing style moderately clear, appropriate for scientific documents and easy to follow o Use of simple language and vocabulary effectively but struggles to use technical language

Glossary of Keywords

Word	Definition	In a sentence
Allotropes		
Dimensionality		
Nanotechnology		
Quantum		
Quantum Confinement		
Kinetic Energy		
Velocity		
Wavelength		
Electromagnetic Spectrum		
Electromagnetic Wave		
Photons		
Particle		
Wave		

Wave-Particle Duality		
Reflection		
Refraction		
Absorption		
Transmission		
Index of Refraction		
Specular Reflection		
Diffuse Reflection		
Armchair		
Zig Zag		
Chiral		
Single-Walled		
Multi-Walled		
Chemical Vapour Deposition		

Emissivity		
Hemispherical Reflectance		
Helical		
sp^2 structures		
Polarization		
S Polarization		
P Polarization		
Array Spacing / Density		

Tutorial 1 – Carbon on the Nanoscale

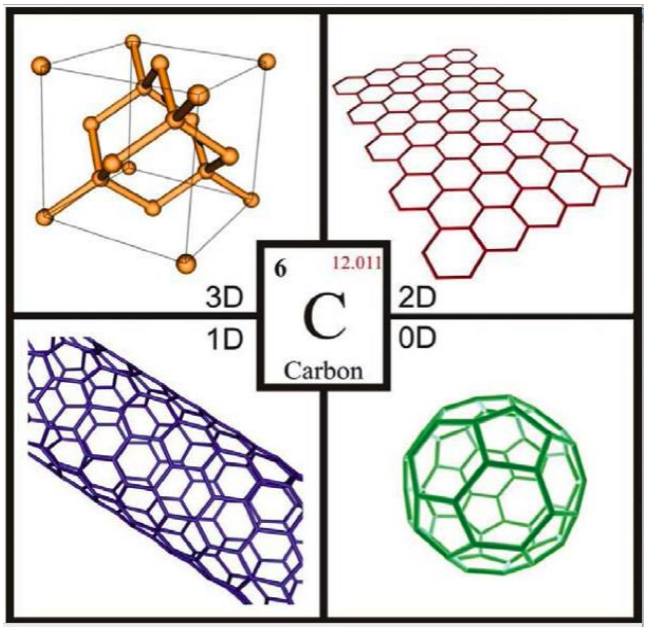


Figure 1[1] Diagram showing the different allotropes of carbon: the zero- dimensional (0D) carbon buckyballs, one-dimensional (1D) carbon nanotubes, two-dimensional (2D) graphene and three-dimensional (3D) diamond.

What is the Purpose of Tutorial 1?

- To introduce the course and the teacher.
- To understand what is nanotechnology and why carbon is a unique material.
- To understand the various dimensions of carbon on the nanoscale.

Keywords

- Allotropes
- Nanotechnology, Nanoscale
- Quantum confinement

Activity 1.1 – Identify three common uses of carbon

On the nanoscale, materials behave differently from their bulk counterparts, due to the effects of **quantum confinement**. From the perspective of materials science, these materials possess intriguing chemical, physical and electronic properties that have attracted the global community of scientists to investigate applications in advanced technology.

Activity 1.2 – Quantum Confinement

Quantum confinement? This term sounds very confusing but lets use a simple analogy. Imagine you are holding a box, and in the box you have **electrons**. As you start to decrease the size of the box the electrons movement becomes confined to smaller and smaller area of space. Now the electrons do not prefer this smaller space, they rather enjoy the freedom of bulk materials.

How might the electrons velocity be affected?

What equation would we need to investigate this strange behaviour?

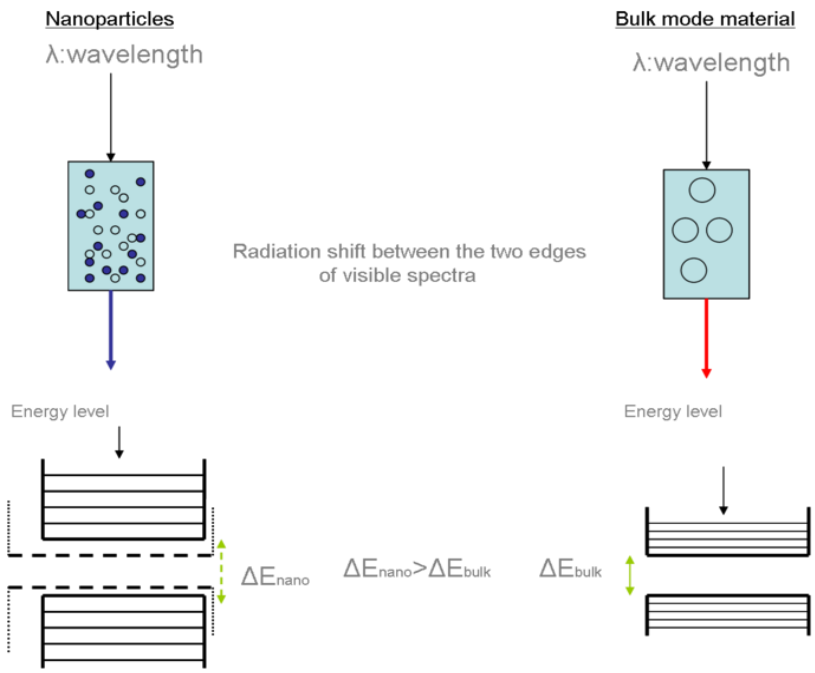


Figure 2 Diagram showing the effect of quantum confinement. In the case of nanoparticles the blue arrow demonstrates a blue shift in light emission due to the dimension of the box decreasing. For bulk materials the red arrow demonstrates that light emission remains red shifted.

Keywords

- Electron
- Kinetic Energy
- Velocity
- Wavelength

Tutorial 1 Homework (Baseline Assessment)

Question

Why do nanoparticles behave strangely? [250 words]

Your answer must:

- Include keywords from tutorial one.
- Written in your own words or if include quotations from other sources, then these should be referenced accordingly.
- Draw any diagrams that will aid in your answer.

Stretch and Challenge

What is the nature of an electron? Is it a wave or a particle?

This homework will be marked using the same criteria for your Final Assignment.

Bibliography

1. Guisinger, N.P. and M.S. Arnold, *Beyond Silicon: Carbon-Based Nanotechnology.* MRS Bulletin, 2010. **35**(4): p. 273-279.

Tutorial 2 – The Absence of Light

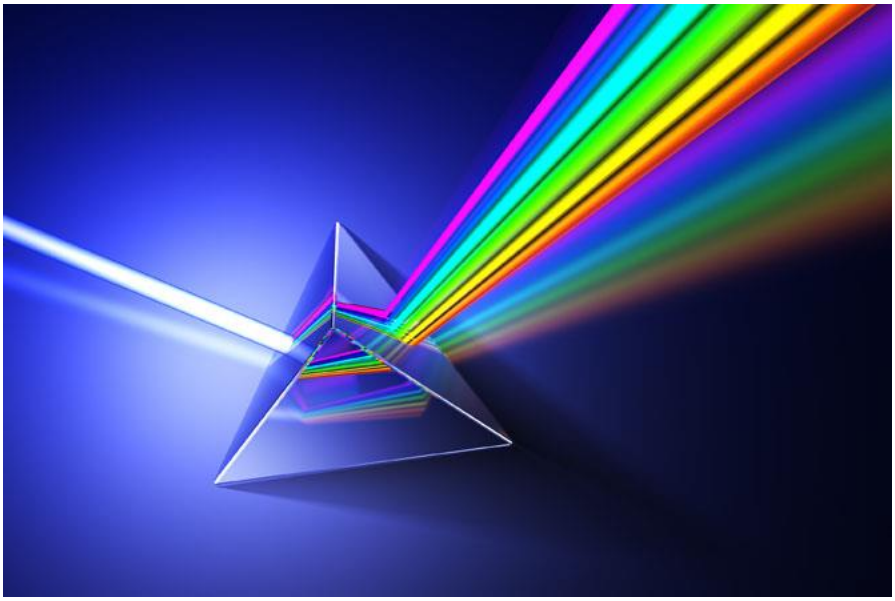


Figure 3 Diagram showing a ray of white light entering a prism. As is enters the prism, the various wavelengths of light are bent and separated. Each colours wavelength bends at different angles.

What is the Purpose of Tutorial 2?

- To review what light is and how it is similar to electrons.
- To understand how light interacts with objects and apply this knowledge to build on what will be learnt in the next Tutorial.
- To build numeracy and analytical skills.

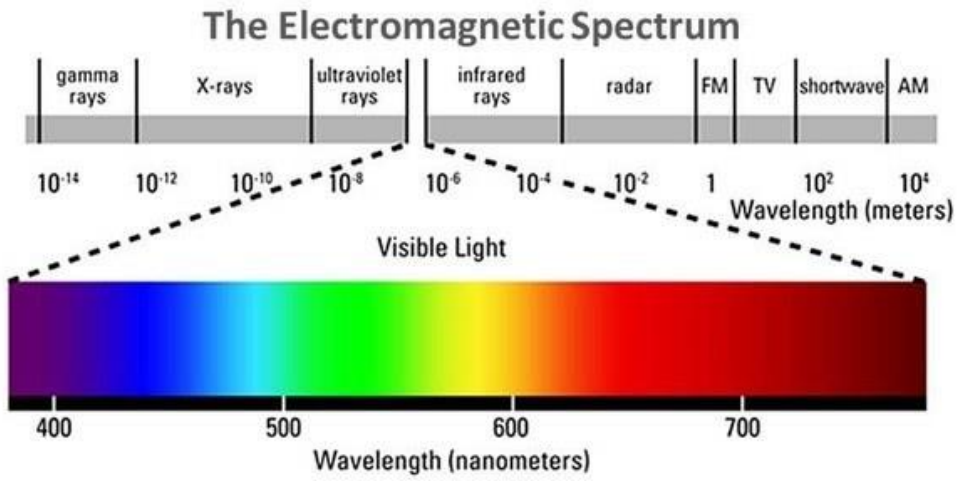
Keywords

- Electromagnetic Wave, Electromagnetic Spectrum, Photons
- Particle, Wave, Wave-Particle Duality
- Reflection
- Refraction
- Absorption
- Transmission
- Index of Refraction

Activity 2.1 – What is Light?

Light is an **electromagnetic wave** in the electromagnetic **spectrum**. Figure 4 shows an image of the electromagnetic spectrum. Within this spectrum, we can see where visible light is located. Light is also composed of small particles of energy called **photons**, which are massless, and travel in waves. Recall from Tutorial 1, your Stretch and Challenge question; What is the nature of an electron? Is it a wave or a particle?

If you have not answered this question, take a moment to **Think – Pair – Share** your thoughts with your group. Write your thoughts below.



What is interesting about visible light and electrons?

Let us take a closer look at what an Electromagnetic wave (EM) is composed of in Figure 5. EM waves are composed of an oscillating magnetic field and an oscillating electric field.

Figure 4 Diagram showing the electromagnetic spectrum.

What about photons? Have we forgotten about them?

A **photon** is an elementary particle that represents a quantum of light. It has zero rest mass and always moves at the speed of light in a vacuum. Photons also exhibit **wave-particle duality**. Therefore it is both a particle and a wave!

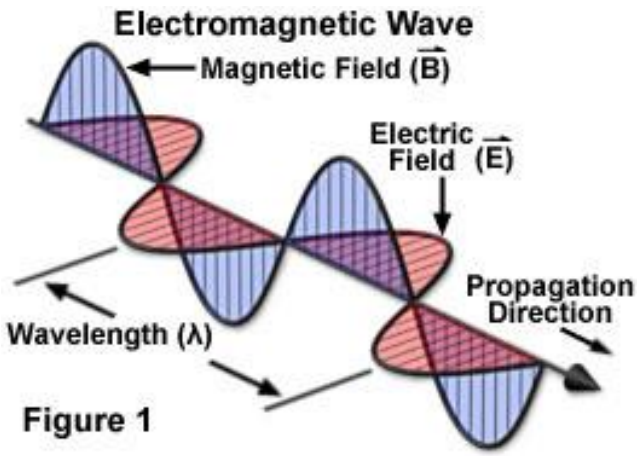


Figure 5 Diagram showing the electromagnetic (EM) wave. The magnetic and electric fields are oriented perpendicular to each other. Wavelength is defined in the image.

Summary

In this part of Tutorial 2 we have covered what light is, further on in the tutorial and course we will tie in what we have learnt here and begin to look at a material that has interesting characteristics once it interacts with light. If you have any questions or require further explanations I am available to discuss them with you. An interactive tutorial to understand EM waves is available for you at:

- https://micro.magnet.fsu.edu/primer/java/wavebasics/index.html

Activity 2.2 – Quantum Structures

Here we are going to revisit Quantum Confinement, however we are going to look at it in terms of energy. Recall our example of electrons trapped in a shrinking box; why would the electrons move faster? What was changing? Okay. Now in Figure 6, we again see the different dimensions but now there is an associated graph. The bulk three-dimensional (3D) structure which shows that electrons in the **conduction band** and holes in the **valence band** are moving freely in all space's dimensions. A **quantum well** is the two-dimensional (2D) structure where one of the three dimensions will be in the nanoscale range of (1 – 100nm) while the other two dimensions remain on their actual size (i.e. electrons are confined in one dimension). Graphene, a thin film of carbon is classified as a 2D structure. The **quantum wire**, which is a one-dimensional structure, has its electrons confined in two dimensions, which simply means that two directions are reduced to the nanoscale range and one dimension remains on its actual size. Nanotubes are classified as 1D structures. Finally, the zero-dimensional structure or **quantum dot** is where all of the dimensions are reduced to the nanoscale (i.e. three-dimensional quantization). While electrons and holes are confined in all three directions, surrounding materials have high energy gap, [2] this quantum confinement of electrons in the three-dimensional quantum dots gives these dots a good property in dealing with light effectively and making it an ideal candidate to form devices such as solar cells [3,4].

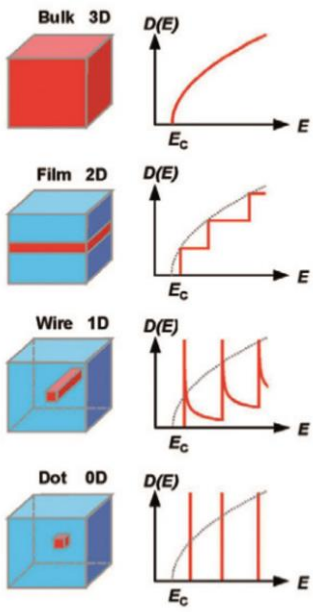


Figure 6 Diagram showing effect of r he Energy levels. Charge carriers are confined in a semiconductor (red) with ne cladding semiconductor (blue). The confinement changes the density of sta -band edge of a 3D semiconductor [1].

How might this new view change your initial perception and understanding of dimensions?

Bibliography

1. Bimberg, D. and Pohl, U.W., 2011. Quantum dots: promises and accomplishments. *Materials Today*, *14*(9), pp.388-397.
2. Rossetti, R., et al., J Chem Phys (1983) 79, 1086.
3. Shockley, W., and Queisser, H. J., J Appl Phys (1961) 32, 510.
4. Friedman, D. J., Curr Opin Solid St M (2010) 14, 131.

Activity 2.3 – Reflection, Refraction, Absorption and Transmittance

Now that we have revisited the dimensions on the nanoscale we are going to focus on one particular dimension for the remainder of the course. The 1D structures called nanotubes made out of carbon.

Recall that reflection is when light bounces off of an object. When the surface is smooth and shiny (i.e. glass or undisturbed water) the light will reflect at the same angle as it hit the surface. Therefore, the angle of incidence is equal to the angle of reflection. This type of reflection is referred to as **specular reflection** and is shown in Figure 7. When light hits a rough surface and reflects in numerous directions, this is referred to as **diffuse reflection** as shown in Figure 7.

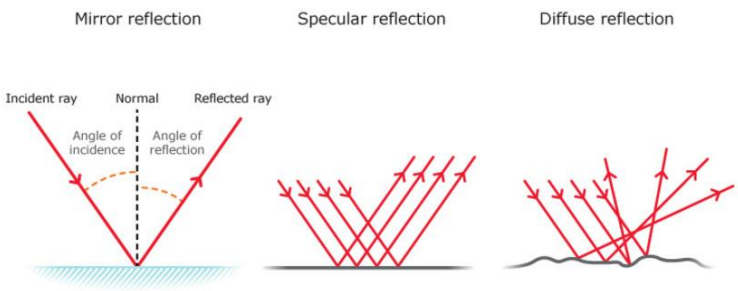


Figure 7 Diagram showing the types of reflection.

Recall that refraction is the bending of light as it passes from one transparent substance to the next. Light refracts whenever it travels at an angle into a substance with a different **refractive index**. When we say refractive index, we are referring to the optical density of the material. Figure 8 shows how an incident ray is refracted into a material. When the ray is refracted, there is a change in its speed. Now how much the ray will bend is dependent on two factors:

- Change in speed
- Angle of the incident ray

Figure 8 Diagram showing the types of reflection.

Now if light is entering a material at some angle that angle will have a corresponding angle of refraction. On the other hand, if light approaches the material at a 90° angle (same as the normal), it will slow down but it will not change direction. Thus its angle of refraction is 0°.

Moving a bit deeper, we find that there are two other processes occurring simultaneously when light is being reflected. These are **absorption** and **transmittance**. Light absorption refers to the transference of energy of the wave as it passes through a material. Transmittance refers to when the light wave moves through the material without being absorbed. Both are shown in Figure 9.

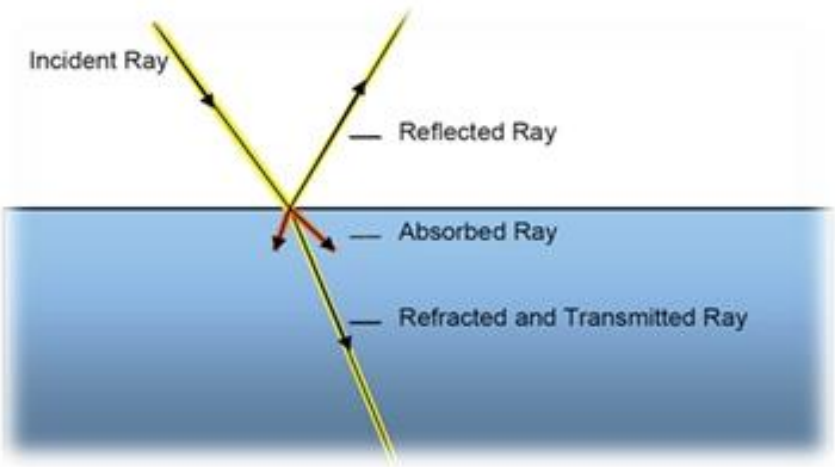


Figure 9 Diagram showing absorption and transmittance.

Activity 2.4 – Index of Refraction

Snell's Law is a very useful equation when investigating light traveling through different media. It is given by the equation in Figure 10.

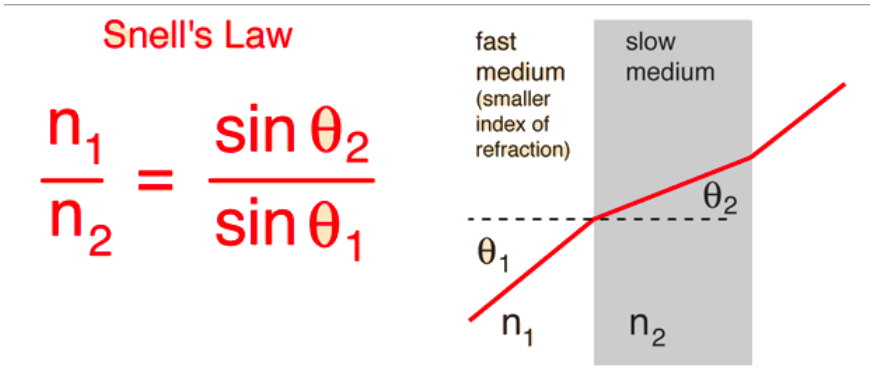


Figure 10 Diagram showing Snell's Law.

Refractive index of some transparent substances

Substance	Refractive index	Speed of light in substance (x 1,000,000 m/s)	Angle of refraction if incident ray enters substance at 20°
Air	1.00	300	20
Water	1.33	226	14.9
Glass	1.5	200	13.2
Diamond	2.4	125	8.2

Figure 11 Refractive index of some transparent substances.

Summary

We have now completed tutorial 2. The title of this tutorial is the absence of light. Now visible light reflecting off of specular and diffuse surfaces is the reason we can see objects. If this were not the case then we would be living in absolute darkness, therefore an absence of light!

Tutorial 2 Homework – Calculating Indexes of Refraction

Use Figure 11 to solve the problems given for this tutorial. Answer al questions below and show each step of your calculations.

Tutorial 3 – Carbon Nanotube Forests

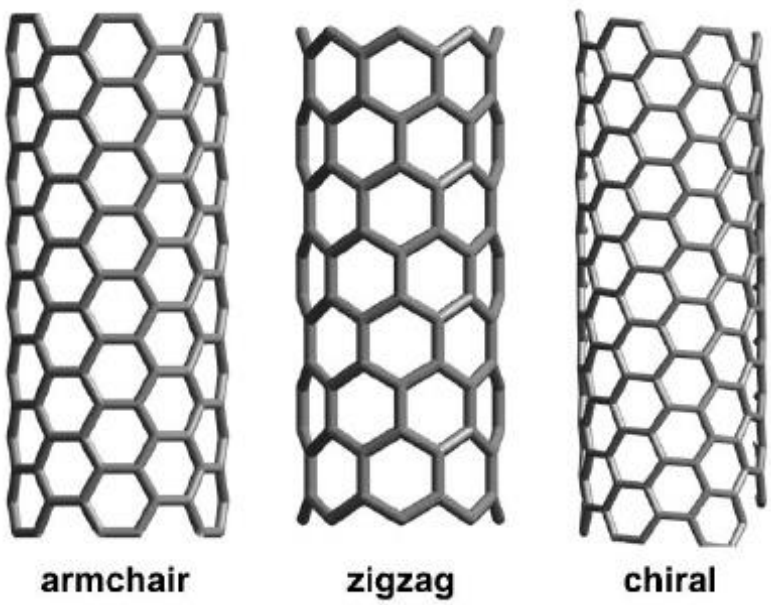


Figure 12 When a sheet of 2D graphene is rolled into tubular form, there are three variants: armchair, zigzag and chiral.

What is the Purpose of Tutorial 3?

- To introduce the 1D carbon nanotube structure.
- To understand how these structures are made.
- To build upon this context of knowledge tying it into the previous Tutorial.

Keywords

- Armchair, Zigzag, Chiral
- Single-walled, Multi-walled
- Chemical Vapour Deposition (CVD)
- Emissivity

Activity 3.1 – Carbon Nanotubes

Carbon Nanotubes are the 1D (quantum wire) form of carbon on the nanoscale. There are two types of nanotubes, **single-walled** and **multi-walled**. The properties of nanotubes are dependent upon how the tubes are rolled up. Figure 12 shows the three different orientations that are possible. **Armchair**, which makes the nanotubes metallic and **zigzag** and **chiral** which make the nanotubes semiconducting. For simplicity the tubes either act as a metal or a semiconductor. In the space below record how to spot the difference between the three orientations.

Activity 3.2 – Creating Carbon Nanotube Forest

Carbon Nanotube Forests are arrays of densely packed vertically aligned tubes. For these dense vertical arrays to be formed a technique called **chemical vapour deposition** (CVD) is the most widely accepted method for growth. It involves two phases (i) the formation and reduction of iron catalyst and (ii) the nucleation and growth of the nanotubes on the catalysts particles. The parameters of growth that are important include catalyst thickness, reactant temperature, reactant time, gas flow rates and growth time. Figure 13 shows a schematic of the furnace in part a, part b shows the two-step process within the four images.

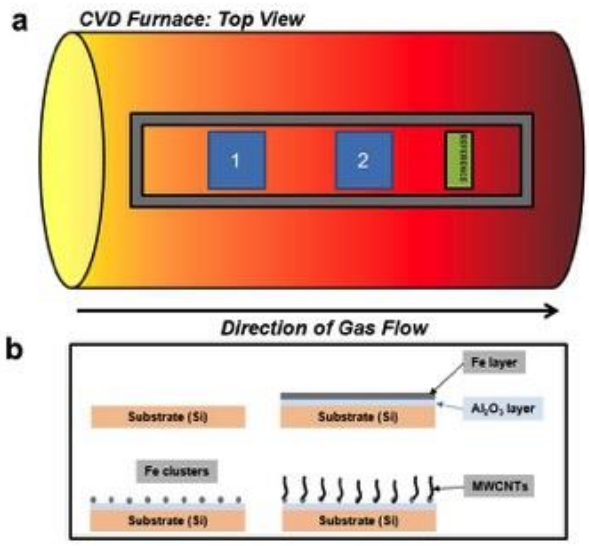


Figure 13 Sketch of (a) CVD furnace and the location of samples with respect to the directional flow of gases (Ar, Ar/H_2O, H_2 and C_2H_4. (b) Growth steps of nanotubes by the CVD method.

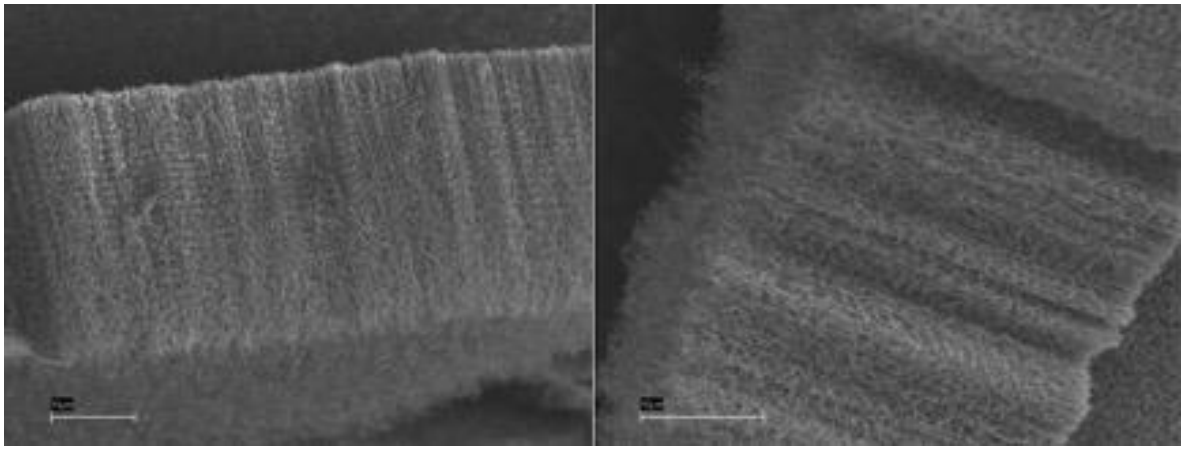


Figure 14 Images of the vertically aligned carbon naotubes.

Activity 3.3 – Optical Properties

Recall that in the Tutorial 2 we learnt about the mechanisms of reflection (R), transmission (T) and absorption (A). As photons interact with the nanotubes there is a change in the index of

refraction at the surface, such that as photons propagate through, these mechanisms occurs simultaneously. The sum of these three optical mechanism components are given by: R + T + A = 1. That is they must add up to one (unity). Now this is a simple way of looking at the interactions. For us to quantify the measurements we have to look at the **emissivity**. During the tutorial we will see why this is and how we get the equation for emissivity (e_λ - read e of lambda);

$$e_\lambda = 1 - R.$$

For example given an emissivity of 0.9984 for a nanotube forest sample, we can substitute this value for e_λ and solve for R, which will inform us of how much light is 'escaping'. In this case 0.16%, thus 99.84% of light is being absorbed.

Sample Number	Emissivity Value	Percent of Light Escaping
1	0.9986	
2	0.9973	
3	0.9994	
4	0.9987	

Given the values for emissivity for the samples, which sample/s would be the best at absorbing photons? Show your work below using the equation provided.

Summary

We have now completed tutorial 3. The title of this tutorial is Carbon Nanotube Forests. Now we have an idea of what we mean by 'forest' and how they are made. We have also learnt that this forest has its own index of refraction.

Tutorial 3 Homework – Paper Review

For this assignment each student will be given a paper that is one of the cornerstones for uses nanotubes forest as light absorbers. For homework read and highlight unfamiliar words and familiar words that we have covered thus far. Do not be concerned about comprehension of all of the material. We will build on this in our next tutorial, Tutorial 4.

Stretch and Challenge

Describe Hemispherical Reflectance. Why is it of importance?

Notes

A black body absorber from vertically aligned single-walled carbon nanotubes

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Communicated by Sumio Iijima, Meijo University, Nagoya, Japan, January 29, 2009 (received for review October 19, 2008)

Tutorial 4 – Trapping Light

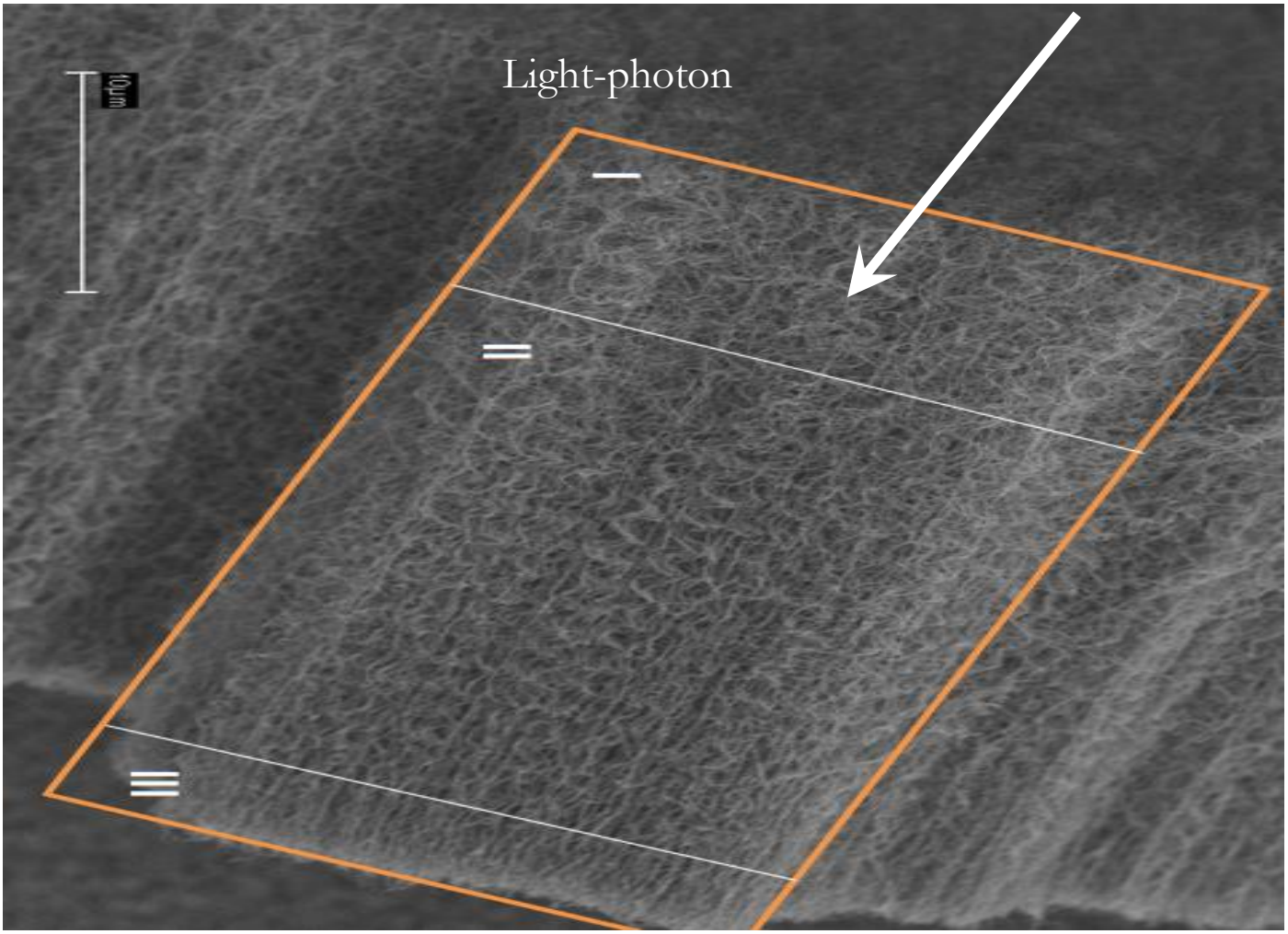

Figure 15 Image of CNTs with a height of ~ 35 μm. **Region I** is the surface of the aligned nanotubes, which exhibit bridge-like interconnections. **Region II** shows highly aligned nanotubes with helical growth and **Region III** is the base where growth begins. Images taken with scanning electron microscope (SEM).

What is the Purpose of Tutorial 4?

- To explain the process of how a photon of light interacts with a nanotube forest.
- To understand the experimental verses theoretical differences of this interaction.
- To bring all tutorials together for comprehension of this topic.

Keywords

- Helical
- sp^2 structures
- Polarization

Activity 4.1 – The Path of a Photon

Recall that in Tutorial 3 we learnt how vertically aligned nanotubes are grown, via CVD. What is CVD? Now we are going to refer to Figure 15 to understand how a photon interacts with this structure. Region I is the first region and is located at the air-nanotube interface and consists of randomly aligned nanotubes with bridge-like nanotube connections. The random surface encourages increased diffuse scattering events along the tubule axes [1]. Additionally, these surface structures decrease the void spaces of the aligned helical nanotubes.

Region II contains vertically aligned **helical** nanotubes. The helical nature is due to pentagon and heptagon defects [2] along the **sp^2 structures**. These tubes due to their angular nature and length allow for the reflectance, transmission and absorption of light in the film. Removal of the region I layer and exposure of region II should further improve the arrays absorbance by lowering the refractive index.

Region III, the final region, contains more aligned nanotubes. However, the nanotubes are considerably short and are close to the substrate. At this height the effects of absorption are reduced due to the limited path for photons to travel. The length effect is also reduced such that we expect the reflectance to increase. This increased reflection from the substrate is a direct result of a glossy surface (specular reflectance).

Activity 4.2 – Theory verses Experiment

In science there is often a contrast between theory and experimentation. Figure 15 is an experimental image that was taken by the teacher while at NASA. Figure 16 is a theoretical model that is often used to explain what scientists believe will occur. The differences between both will now be discussed in class.

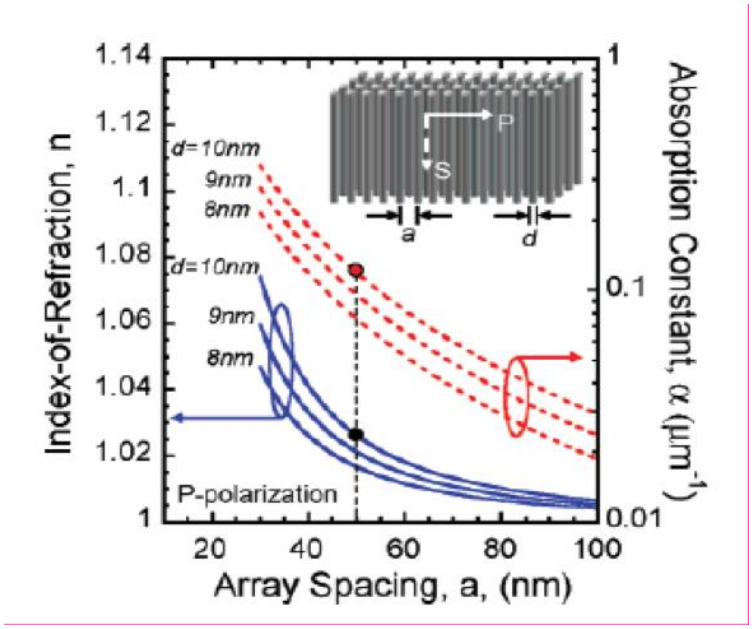

Figure 16 [3] Calculated effective index of refraction and the absorption constant plotted as a function of nanotube spacing. A schematic of the nanotube array and the **s** and **p** light **polarizations** is displayed in the inset.

Notes

What is s polarization?

What is p polarization?

Why is array spacing important?

Summary

We have now completed tutorial 4. Now we understand the importance of 1D carbon in terms of how it traps light in a 'forest' of nanotubes. We can also expand our thinking on other types of applications for the future. Be extremely proud, you are now budding young nano-scientists!

Tutorial 4 Homework – Vantablack

For this assignment you are going to look at practical applications for the vertical arrays of carbon nanotubes. In order to do so you will have to visit the website of the company Surrey Nanosystems based in the UK.

https://www.surreynanosystems.com

Once here, click on the Vantablack tab and review the following links:

- The Science
- The visual impact of Vantablack
- Watch the Big Wrinkles video

List 2-3 current applications of this material.

Stretch and Challenge

What does 'Vanta' mean in the word Vantablack?

Bibliography

1. Garcia-Vidal, F., J. Pitarke, and J. Pendry, *Effective medium theory of the optical properties of aligned carbon nanotubes.* Physical Review Letters, 1997. **78**(22): p. 4289-4292.
2. 2. Lehman, J.H., et al., *Evaluating the characteristics of multiwall carbon nanotubes.* Carbon, 2011. **49**: p. 2581-2602.
3. Yang, Z.P., et al., *Experimental observation of an extremely dark material made by a low-density nanotube array.* Nano Letters, 2008. **8**(2): p. 446-451.

Tutorial 5 – Review

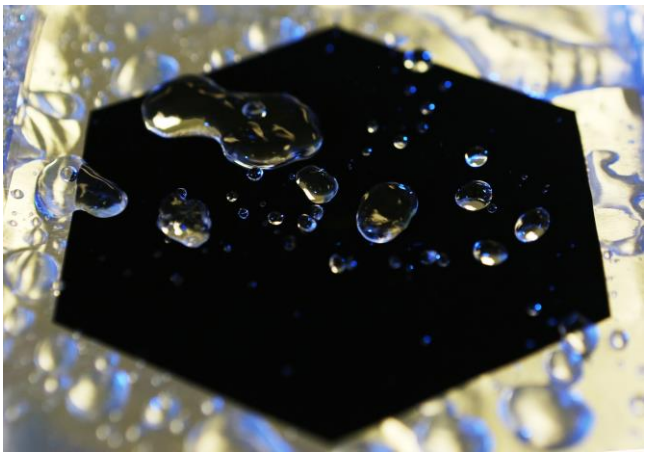

Figure 17 [1] Image courtesy of Surrey Nanosystems. Vertically aligned nanotube array.

What is the Purpose of Tutorial 5?

- To review the material covered in Tutorials 1 to 4
- To identify any misconceptions and correct them
- To create a draft for the final assignment presentation

Activity 5.1 – Questions

Recall the material covered, are there any questions that you have? We will use this time to address them and cover any **misconceptions**. Your tutor is available for any questions that you may have.

Notes

Activity 5.2 – Final Presentation Preparation

The purpose of your final assignment is to allow you to confidently talk to others about what you have learnt. This is part of the process of being a scientist. Take the time now to create a rough draft of what you will like to discuss. You may use any of the resources that have been given to you during these tutorials.

Presentation Ideas:

- Why are vertically aligned nanotubes more desirable than randomly oriented nanotubes?
- Why is carbon a unique material on the nanoscale?
- How is light trapped in a 'forest' of nanotubes?
- Why was this type of technology developed and what are future benefits?
- Describe how nanotubes are grown and the important parameters that are necessary.

Notes

Bibliography

1. Surrey Nanosystems. https://www.surreynanosystems.com/media/images-videos

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

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.

    a. 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].

    b. 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.

    c. 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.

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UNI PATHWAYS

Course Title

Key Stage 4 Programme

researchersinschools.org