The Scholars Programme

STEM Problem-Set Course Design Guidance

The Scholars Programme

2022-23

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Section A: Scholars Programme overview

Programme Overview: course structure

The Scholars Programme is delivered through a series of small-group tutorials. Pupils begin the programme by attending a launch event with one of The Brilliant Club's university partners. You will then meet pupils for the first time in Tutorial 1. We recommend that you use **tutorials one to four** to deliver your course's content.

Launch Event

Tutorials 1-5
Usually once a week, delivering to two groups of six pupils

Tutorial five should be reserved for **revising key content and setting up the final assignment**. Following tutorial five, pupils will complete a draft of their final assignment.

Draft Assignment

Tutorial 6 (one-to-one feedback)

Tutorial six will be a series of one-to-one meetings with each pupil where you will give individual feedback on the pupils' draft assignments. Further guidance and training will be given at the training weekend. You do not need to plan any content for this tutorial at this stage.

Final Assignment
You will mark the final assignments, then take part in national moderation process

Tutorial 7 (one-to-one feedback)

Pupils then write and submit the **final assignment**. Once the marking and moderation process is complete, you will deliver final one-to-one feedback in **tutorial seven**. Again, guidance will be given on delivering this through tutor training.

Graduation Event

The rest of this document will guide you through a step-by-step process to design your final assignment and the content of tutorials one to five of your course.

How to use this guidance

Welcome to the **STEM Problem Set Course Design Guidance**. Completing the **STEM Problem Set Course Design Template** is your first step towards creating your course. This guidance will help you plan a course of pupils in the middle stage of secondary schooling who are aged between 13-16 years old.

This document is designed to help you complete your course design template and to act as a reference point when you are designing your handbook. Once you have completed your course design template, you will receive feedback from a qualified teacher or subject expert and can then begin designing your handbook.

You will be emailed a link to your Course Design Template upon completion of your online training modules. We strongly recommend that you complete the online course design template **within two weeks** of receiving your Course Design Template. This will allow us to provide you with feedback on your suggested course in a timely manner before you begin creating your handbook.

This guidance has been put together to support you through the course design process by:

- Providing a step-by-step guide to completing the Course Design Template
- Breaking each tutorial plan down into key components
- Answering a series of commonly asked questions about course design in general
- Providing advice about pitching your materials and handbook at the right level
- Providing a bank of tutorial activities (Appendix 2) and further reading (Appendix 3) to prepare you for next steps in the planning process.

Course design checklist

Use the checklist below before submitting your course design template and when completing your handbook.

Section	Template	Handbook
Exciting course title		
Course Rationale		
Final Assignment Essay Question		
Final Assignment Problem Set Outline		
Baseline Assignment Essay Question		
Baseline Assignment Problem Set		
Learning objectives and key questions		
Initial activity/hook		
Discussion topics/questions		
Resources (links, readings, etc.)		
Homework		

Section B: Choosing your topic

Choosing the right topic for a new Scholars Programme course makes designing and delivering your course much easier and it is therefore worth spending some time carefully thinking about your topic before you get started. A Scholars Programme course is constrained by multiple factors, primarily:

- Contact time available with pupils
- Accessibility of topic

Scholars Programme courses are supra-curricular, which means they typically cover content not taught in schools. This does not mean that your subject cannot be something school-aged pupils learn about, but it should go into more depth than the school curriculum allows.

In scientific fields, knowledge is often built up throughout education. Whilst many broad scientific areas are covered in curricula, pupils will lack the knowledge of many of the more complex scientific topics studied at university and will not be familiar with many scientific research skills, such as reading academic papers. It can therefore be challenging to design a course around your research that is accessible to pupils aged 13-16, and deliverable in the time available. You should select your topic carefully, and consider the key skills and knowledge pupils will need to succeed.

Including a problem set

You are reading this guidance because you believe your topic will allow for a **problem set** as part of the baseline and final assignments, in addition to the written aspects. This will be particularly applicable in physics, mathematics and engineering courses. Including a problem set will allow you to include the more mathematical content of your research throughout the course.

If you do include a problem set, then you will need to ensure that when you choose your topic, the problem element is at least 50% of the content, otherwise pupils will not make adequate progress in this part of the course. Pupils are used to lots of practice to excel in mathematics and will need your support to complete enough practice here.

Given that STEM courses usually need to contain a lot of new content, we generally recommend going for a 'breadth' approach in your course. Rather than choosing to focus specifically on your narrow PhD topic, consider designing a course that steps back and considers the bigger picture, or the more general area that your PhD falls within. It is worth remembering that for many pupils this will still mean they are studying a subject in much more detail than they have before.

Below are some examples of PhD topics within STEM, and how they can provide the basis for a broad Scholars Programme course.

Examples

PhD Research area	Scholars Programme course title	Topics included in the course	Type of Course
'Molecular Biology of Neurodegenerative Diseases'	The making and breaking of memories	- Basic brain anatomy - Neuron biology - Neurodegenerative disorders.	Essay based
'Ultrasound mediated therapies for treatment of biofilms in chronic wounds'	The bacterial biofilm: Misunderstood microbes or public health hazard?	- Antibiotic resistance - Public health - Microbiology	Essay based
'Quantum Error Correction'	Should we build a quantum computer?	- Boolean logic - Quantum computing - Ethics of quantum computing	Problem Set
'Cellular-resolution volumetric structural and functional imaging of tissue using fiber optic needle probes'	Seeing the Small With the Small: Designing Miniature Microscopes for Medical Imaging	- Medical Imaging - Microscopy - Endoscopy	Problem Set
Finite Group Theory	Are some infinities bigger than others?	- Basic set operations - Functions - Cardinality	Problem Set
Particle Physics	Symmetry, Symmetry Breaking and Why the Universe Doesn't Annihilate Itself	- Symmetry - Time dilation - Matter and anti-matter	Problem Set

Pitching your course at the right level

Pitching your course to the appropriate level for 13-16 year old pupils can be one of the most daunting parts of designing a new Scholars Programme course. This section aims to provide some guidance on how to pitch your course at the appropriate level and includes some pointers and places to find further information about the level of science your pupils will have studied.

Key information:

- For The Scholars Programme, you should plan to deliver your course to pupils ages13-16 years old.
- The course should be tailored to your PhD research so that the pupils are learning about something beyond the curriculum. However, it is often more appropriate to use your general area of research as a starting point for the course and include specifics of your research as examples given how specialised your own research is likely to be.
- Use the information in Appendix 5 to give you an idea of the level of the work you should be setting, based on pupils' prior knowledge.

Whilst pupils are often able to grasp surprisingly complex topics in tutorials and their own work, they need to be supported to build up both the subject knowledge and relevant skills in order to do this.

Problem Sets and Pitching for Mathematical Skills

It can be challenging to pitch a problem set correctly. The problem element of your course should have some questions that will be accessible to all pupils but should also include questions to stretch and challenge your pupils.

To ensure you support pupils to develop their mathematical skills you will need to consider the skills you want pupils to learn throughout the course. Pupils will be used to spending entire weeks learning one key concept in mathematics while you will need to balance developing new mathematical skills with learning to engage in scientific research in a short space of time. When you plan your course, you need to ensure that you do not try to teach too many new concepts. Stick to a clear path of skill development which ensures pupils learn what is needed whilst also including what will interest and excite them, rather than lots of skills that may link to the learning somewhat but pupils won't be able to grasp in the timeframe.

Pupils will be fascinated to learn how the mathematics they learn in school can link to your research so use that as your starting point before challenging them further.

Pitching for content

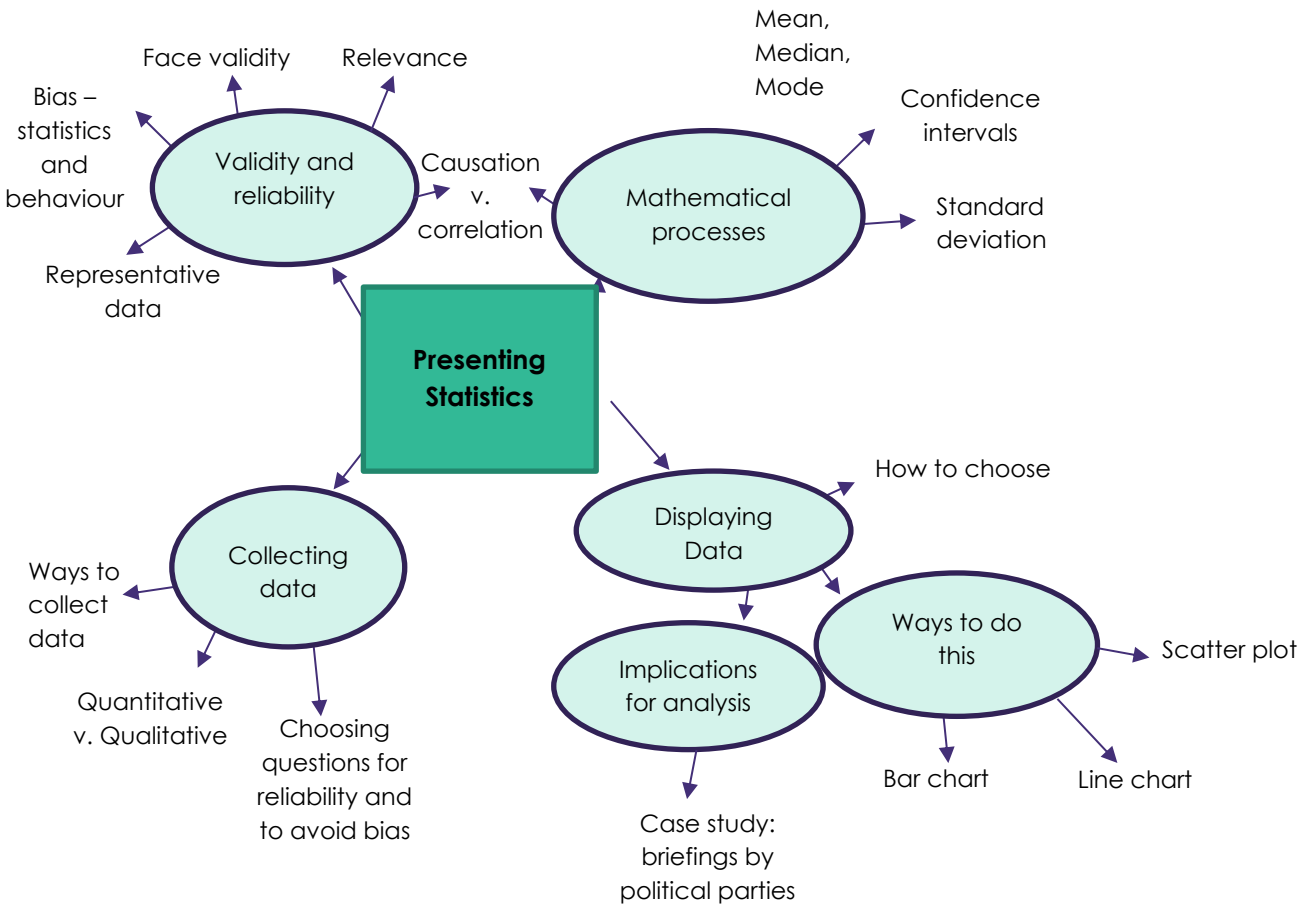
Complex topics can be grasped by students if they are able to build up to them, link to pre-existing knowledge or relate new ideas to more familiar situations. Sometimes, you will need to explain a complex idea, concept of process. This can feel like climbing up a very long ladder; if pupils miss one rung, they'll be stuck and won't be able to carry on. See section F for some ways of supporting pupils to grasp complex STEM concepts in an interactive way, including how to use metaphors, imagery and activities to help break down complex scientific ideas.

Think along the lines of explaining the topic to a grandparent or member of the public…. people can grasp complex topics, but only when broken down into chunks!

Before finalising your course's focus, you may find it helpful to write out the core question or theory you wish to look at. Then map out all the related concepts that you could cover in each tutorial. This will help you ensure you have enough material so that pupils can complete the course while also giving you the opportunity to cut out material that is not essential. You should aim to cover no more than one or two concepts in each tutorial. See below for an example of this using the topic of 'Antibiotics – Importance and testing'.

Remember, pupils on The Scholars Programme should be **stretched and challenged** to work at a key stage above their current learning level. The subject specific content and skills tables (Appendix 5) give examples of the type of content and skills pupils should be demonstrating at pupils' current learning level, and at the level at which your course should be pitched and should provide you with an idea of the level of the work you should be setting.

Example of breaking a topic down into key concepts:



In pitching content, it is also important to consider the needs of pupils based on their age, as we have a duty of care to safeguard pupils. Remember that your course should be pitched at pupils 14-16 years old, which may have the following implications

- Carefully consider which topics may be sensitive for pupils. In doing research on sensitive topics, sometimes researchers can develop a blindness for what may be sensitive or triggering to people outside their field. While these topics can have clear pedagogical purposes, it is important to consider how they will be received by pupils with a diverse range of experiences. For example, topics such as animal testing, medical details of injuries, survival rates of diseases, trauma, medical ethics may be particularly sensitive for 14-16 year olds. In pitching your content, we encourage you to carefully consider if any the concepts you've identified may be sensitive for young people, and how you will present them to pupils.
- The above is not an extensive list, but a good sense check would be to consider if you would explain a topic in an equivalent level of detail to a grandparent or to a non-academic layperson. If you would adapt some of the details or resources for this audience, consider how you could do the same for your pupils. If it is important to discuss a sensitive topic in detail, please use your course design template to suggest how you would approach this in a tutorial, and the Brilliant Club staff member providing feedback on your plans will help you continue to solidify your approach further.
- This applies to topics, but also the images and learning resources you choose to include in your handbook. For example, consider the age rating of any film clips as these should not be rated over PG-13 or 12A. You should also consider the content in any readings you choose to include in your handbook and avoid any overtly graphic descriptions of potentially sensitive topics. Where a topic might be sensitive, we encourage you to include a content warning so that pupils can be prepared for the upcoming material.

Pitching for academic skills

There are some skills, for example, reading scientific literature and analysing scientific data, that pupils need to be supported with in order to be able gain and access more complex concepts.

Reading scientific papers is a skill and is not something generally covered in school. Most pupils will be unaware what primary literature or reviews are, let alone how to read them. If you are keen to get pupils to engage with scientific literature in your tutorials (which is a great way of showing them what research is like, as well as providing them with the means to do independent research), try the following:

- Provide pupils with a graph/figure from a paper. Don't expect them to be able to analyse it straight away. You could turn this into an activity where pupils can work together to understand the information.
- Include images/data from your PhD and unpick this with pupils in tutorials to build up their confidence in analysing data. Then get them to apply similar skills to other data in published papers.
- Avoid asking pupils to digest whole papers or reviews alone – you could provide a section, figure or abstract to make the research more accessible.
- If you are including whole research papers in your handbook (e.g. if they are hard to access online), put these as appendices rather than in the tutorial section.

Section C: Marking and assessment

What are the final assignment and baseline assessment?

	Baseline Assessment	Final Assignment
What is it for?	Checks the level of **academic skills and prior knowledge** and allows you assess if you need to adjust your course content to effectively support pupils.	Provides a final grade for measuring pupil progress in **subject knowledge and academic skills** made during the programme and informs final feedback given to students.
How long should it be?	250 words and 25-50 marks from a problem set.	1,000 words and 50-100 marks from a problem set.
What marks should I give?	Marks submitted via the VLE, but **not given to students**	Marks submitted via the VLE and given to students in feedback tutorial
When is it set?	As Tutorial 1 Homework	In Tutorial 5 (so that a draft can be produced for Tutorial 6)

When including a **problem set**, this will make up half of the final assignment – a written question of half the total length for that key stage (so 1000 words for 13-16 year olds) should also be produced. As with university-level work, it's important to design problem sets that ensure a spread of marks, rather than all pupils achieving 100%.

The assignment should be marked based on the STEM problem set mark scheme (see Appendix 1B), which involves assessing less written competencies than the standard mark scheme. You should ensure you set problem questions in both the baseline and final assignments to ensure you can show progress across the course.

Marking the final assignment and baseline assessment

Essay Section Mark Scheme

Both the final assignment and baseline assessment essay components are marked against the standardised mark scheme, which can be found in Appendix 1. In order to effectively use this mark scheme, the baseline and final assignment should allow pupils to demonstrate all skills from the mark scheme in some form.

We use standardised mark schemes for Humanities and Social Sciences and STEM placements – different versions of the mark scheme are available for Key Stages 2-3 and Kay Stages 4-5.

The mark schemes were developed in collaboration with an assessment expert at the University of Cambridge, who specialises in improving the quality of exam questions and mark schemes.

Problem Set Mark Scheme

We do not provide a specific problem set mark scheme, as each problem set will be so unique. As outlined below, you will provide a percentage for each pupil's problem set mark. We therefore suggest making the total marks available 25 or 50 for the baseline assignment, and 50 for the final assignment, but this is ultimately up to you. When you create the problem set, you should also create a mark scheme to ensure you mark each pupil's work fairly. This mark scheme will also be used to support the national moderation process.

What marks should I give for the final assignment and baseline assessment?

For the baseline and final assignment, you will need to submit a percentage for both the problem set and the written component of the assignment. To mark the written portion, each of the three criteria in the mark scheme must be given a mark out of 100; the average of these three marks will be the final mark for the written component.

The final overall mark the student receives for both assignments will be the average score between their problem set mark and their written mark.

What type of grade should I give the pupils?

For the final assignment pupils will be given marks that are graded using a university-style system as follows:

Grade	In England, Northern Ireland and Wales, the pupil is…	In Scotland, the pupil is..
1st	Performing very well at Key Stage 5	Performing very well at Senior Phase of CfE (National 5/Highers)
2.1	Performing well at Key Stage 5	Performing well at Senior Phase of CfE (National 5/Highers)
2.2	Performing very well at Key Stage 4	Performing very well at Third/Fourth Level of CfE
3rd	Performing satisfactorily at Key Stage 4	Performing to a good standard at Third/Fourth Level of CfE

***NB: The Scottish system does not map directly onto the Key Stage system in England, Northern Ireland and Wales. Tutors should aim to design a course that is challenging for S3 and S4 pupils.**

The level descriptors should be treated like success criteria: if a pupil produces work that falls mainly in the 1st descriptors they should be awarded a 1st overall; if the work does not usually achieve a 1st but is above a 2.2 they should be awarded a 2.1. You will also provide your students with written feedback on their performance in the final assignment

When including a problem set, it is very important to ensure that your problem set allows the pupils to perform well, if they have a clear understanding of the key concepts. We encourage you to look carefully at the relevant national curriculum to determine if pupils will have the foundational mathematical skills to carry out any calculations. However, much like university, we do not expect pupils to achieve 100% except in very extreme circumstances.

Please use the same mark scheme and criteria for the baseline assessment and final assignment. You should give students feedback on how they performed in the baseline assessment in line with the mark scheme, with clear instructions for how to improve their work. However, please **do not share** baseline marks with students.

What about checking understanding at other times in the programme?

Tutors should check pupils' understanding throughout the programme and adjust the delivery of their course as necessary. Pupils' contributions in tutorials and their homework are good opportunities for doing this. It can be helpful to plan specific questions to ask pupils in order to check they have understood key information before continuing with the planned content of a tutorial. Examples of how to do this will be discussed at the training weekend.

Section D: Final Assignment

Creating a final assignment written task

Considering and planning the broad topic of your course, and breaking this down into key concepts, will allow you to establish which content and skills need to be focused on from your ideas. **The final assignment should be the first part of the course that you plan in detail.** This will allow you to work backwards and ensure that you cover all the key concepts and skills in your tutorials. The final assignment for your course should focus on, and be clearly linked to, one or more aspects of the topic on which you will base your course.

Regardless of whether your course is essay-based or includes a problem set, there are a range of different approaches to framing your final assignment. Your final assignment written task might take a synoptic look at the content of the whole course; it might culminate in one key question that is built up to in the sequence of tutorials and set as a final assignment or you may decide to give pupils the chance to choose the focus for themselves. A successful final assignment written task usually has some links to all the tutorials, as well as the scope for pupils to research the topic independently.

Creating a final assignment problem set

For many, the concepts for your problem set may come much more easily than designing the written task. It is important to start your course plan by planning what you want pupils to do in the final assignment problem set task to ensure that you can build enough time into each tutorial to develop the pupils' skills and understanding to successfully answer the problem set work.

You may choose to set a number of problems, increasing in difficulty, as your problem set task. Alternatively, you could set pupils a large task to tackle though, this approach is not as popular. With either method, **it is important to write a mark scheme** with the problem set, to ensure that what you are asking of the pupils is clear, you mark each individual pupil fairly, and that you can easily give the pupils a final mark as a percentage. Pupils will be used to looking at the mark scheme or number of marks awarded for each question and so including this in the handbook will be useful for them.

However you phrase the final assignment sections initially, you may end up rewriting them completely several times before you are happy with it. This is normal and part of the challenge of designing a course.

Things to do when designing your final assignment:

- Ensure that you will have enough time to teach the content needed to successfully answer both the final assignment written task and problem set throughout the course rather than be too ambitious – it can be difficult to balance the range of skills needed to teach in a course that includes a problem set.
- Be specific and clear with the final assignment question and what you are asking pupils to write about. Consider the ways in which pupils could misinterpret the final assignment and ensure you clarify these points.
- Students often benefit from the mark scheme being broken down – you can be explicit with what you expect from them. E.g. indicate that they should include, diagrams, independent reading and examples as part of their essay.

- You should most of tutorial 5 discussing the final assignment with students and supporting them to think about how they can make links in their assignment to other tutorials and their own independent research.
- The final assignment word count is 1000 words when a problem set is included.
- Include the number of marks each question in the problem set can be awarded.

Things to avoid when designing your final assignment

- Asking pupils to design an experiment as part of their final assignment – whilst you may want to discuss experimental design in tutorials, it is difficult for pupils to display the assessed competencies if producing a final assignment based on experimental design. If this is something you'd like to include, consider making this part of a broader essay question.
- Very specific final assignment questions – your assignment question should allow pupils to include and link a range of topics from within the tutorials, as well as include their own independent reading and research.
- Expecting pupils to read and analyse primary scientific literature and produce a literature review for their final assignment. Supporting pupils to engage with scientific literature is great and is really encouraged in The Scholars Programme, but this is something to include as part of the final assignment, rather than expecting them to produce a full literature review for the assignment.
- Asking pupils to generate a data set in their final assignment – if you are hoping to include data analysis as part of your final assignment, it is, generally speaking, better to include a pre-generated data set that pupils can use, rather than asking them to create a dataset themselves which can be easily misinterpreted and often leads to confusion with the final assignment.

Breaking down the final assignment

For most people at university, essay-writing or completing a piece of written coursework is something that is expected. For pupils taking part in The Scholars Programme, writing a 1000-word essay in addition to completing a problem set may seem daunting. Pupils tend to produce a more thorough and confident piece of written work if this is first broken down into parts.

It is most useful when tutors provide additional information for pupils, outlining how they can best use the tutorials and the mark scheme, or detailing what is expected in the final assignment. See some examples below.

Example final assignment:

This final assignment consisted of both a problem set and a research question. Below is a section of the problem set and the essay question.

Final assignment problem set (50 Marks)

Jane wants to design an endoscope that will help her with diagnosing breast cancer. S he knows that she wants a resolution of at least 2 µm (2 µm or less) to be able to accurately determine the boundaries between healthy and cancerous tissue. She plans to start by building her endoscope with bulk lenses. She plans on using an imaging technique called autofluorescence imaging, which is a fluorescence microscopy technique. Autofluorescence relies on substances that naturally exist in the body and fluoresce when exposed to a certain wavelength of light. The substance that Jane wants to excite is sensitive to light of 532nm. The endoscope will be composed of two lenses: L1 will collimate a beam coming from an optical fibre and L2 will focus the beam to the desired spot size when it exits the endoscope.

1. Is 532 nm light visible? If so, what colour is it? What is the frequency of 532nm light? **(3 Marks)**
2. In order to achieve a spot size of 2 µm, what will be the required numerical aperture of L2? You can round your answer to 2 decimal points **(3 Marks)**
3. What will be the depth of field images acquired with this endoscope? **(3 Marks)**
4. Jane would like the beam to have a diameter of 200 µm in the collimated region. What should be the focal length of L2? Note that the beam is focusing in air, and the index of refraction for air is 1. **(4 Marks)**
5. To deliver light to her endoscope, Jane will be using optical fibre. The beam coming out of the fibre has a diameter of 50 µm and a numerical aperture of 0.22. What will be the angle of divergence of the light exciting this fibre? Remember that the index of refraction for air is 1. You may give your answer in radians or degrees. **(3 Marks)**
6. How far should L1 be placed from the end of the fibre to allow the beam to expand to a diameter of 200 µm? You can round your answer to the nearest whole number. What should be the focal length of L2 so that it will collimate the light coming from the fibre? Why? **(5 Marks)**

Final research question (50 Marks)

Explain how endoscopes can be designed for a specific application and why this is important (1000 words)

- Describe what an endoscope is and discuss the advantages and disadvantages compared with using a table-top microscope
- Are endoscopes useful for medical diagnosis? How?
- What criteria are important to consider when choosing the right tool for the job? Why? You should discuss the choice of imaging technique, contrast and resolution appropriate for a specific application. You should also mention any trade-offs in design choices; for example: how does numerical aperture link to probe size and resolution?

Gavrielle Untracht – Seeing the Small with the Small: Designing Miniature Microscopes for Medical Imaging

Example final assignment 2:

Final assignment problem set (50 Marks)

When attempting the problem set questions you should first establish what basic principle is involved. Write down any equation which you think will be relevant and clearly state the information you have available (which variables in your equation are known and which are unknown?). If you can't see how you're going to calculate the final answer, consider what you could calculate which might be a useful intermediate result. You can also start from the answer you want and work backwards. What intermediate result might be useful in helping you get to the final answer? By working forward from the information you have and backwards from the information you want you might be able to meet in the middle.

Be careful with units. It's always safer to first convert everything into SI units (m, Kg, s, J). This will give you an answer in SI units which you can then convert into a more convenient unit at the end of the question (for example if you're talking about the lifetime of a star is it more sensible to talk about seconds or years?). Be careful when you consider reference frames. Which is the proper time, and which is the 'dilated' time? Remember that marks are awarded for partial solutions so make sure you carefully show your working.

1) Consider the transformation $x \rightarrow \frac{1}{x}$ (the transformation on numbers where each number is transformed into its reciprocal e.g. $2 \rightarrow \frac{1}{2}$, $\frac{2}{3} \rightarrow \frac{3}{2}$ etc). Which number(s) if any would be unchanged by this transformation? Would you describe this as a continuous or discrete transformation? Is this transformation symmetric under addition? Is it symmetric under multiplication? (You can use examples or better still algebraic proof to justify your answer).
2) A spaceship travels past you at half the speed of light. When a year has passed on your spaceship how much time will you observe having passed on the moving spaceship?
3) A π^0 particle has a lifetime of 3×10^{-17} seconds. A physicist is attempting to observe the particle before it decays. The particle detector he is using has a spatial resolution of 2×10^{-6}m. (This means the detector cannot observe any particle which travels less than this distance before decaying). What is the minimum speed the particle must travel in order to be detectable?
4) A particle is observed moving at 99% of the speed of light. It travels 0.1m before decaying. What is its lifetime (in its own reference frame)?
5) Assuming that CPT is an exact symmetry of nature explain why a violation of CP symmetry implies a violation of T symmetry.

6) The τ particle (a particle similar to the electron and muon but thousands of times heavier) has a mass of 3×10^{-29}Kg. If this particle annihilates with its antiparticle how much energy will be released?
7) During the 'main sequence' phase of a star's lifetime the energy released by the star is due to the nuclear fusion of four hydrogen nuclei into a helium nucleus. The mass of the hydrogen nucleus is 1.67×10^{-27}Kg and the mass of a helium nucleus is 6.64×10^{-27}Kg. The power output of the sun is 3.85×10^{26}Watts (joules per second). Initially the sun had a mass of around 2×10^{30}Kg and was composed mainly of hydrogen. Use this information to produce an estimate for how long the main sequence of the sun will last.

NB: Research question available on next page

Final research question (50 Marks)

Symmetry and symmetry breaking have been central to modern physics over the last 150 years and continues to play a pivotal role on the road to probing key unsolved problems at the heart of our understanding of the universe. Produce a 1000-word essay detailing to what extent you agree with this statement.

When writing your essay, you should be careful to introduce the topic and define the terms you use (for example symmetry, discrete, continuous etc). When discussing various symmetries, you should explain how they came to be discovered and distinguish between a symmetry which is assumed to be true, has been proved theoretically to hold or has been experimentally verified. You should also discuss which particular aspects of symmetry and symmetry breaking are important in our current search for 'new physics'. It is important to reference the source of your information and if you are quoting a source directly you should use quotation marks to make this clear. Your essay should be understandable to an intelligent reader who is unfamiliar with the topic.

Lauren Martin – Symmetry, Symmetry Breaking and Why the Universe Doesn't Annihilate Itself

Section E: Backwards Planning

What is backwards planning?

Imagine you were building your city's next great skyscraper. You'd likely start by drawing up plans and then thinking back from the finished product to decide what tradespeople you might need and when you will need them. You wouldn't gather the concrete trucks, interior designers, electricians and plumbers all together at the very start and then sort things out. In pedagogical scholarship, this approach is called backwards design.

Backward Design or '**Backwards Planning**' refers to the process of planning a course or sequence of learning, where the designer focuses on the desired **end result** of the project first. Rather than beginning the planning process with a focus on a specific subject area or a series of activities, the design process begins by asking what learners **should be able to understand and do** at the end of the course.

As mentioned above, while you have begun to draft your final assignment is not set in stone at this stage. You may want to revise it as you keep thinking about your course but keep this question in the forefront of your mind throughout your planning. Because PhD subjects are so complex, your course should focus the limited time you have on the concepts and skills pupils most need to be successful on their final assignments. Keeping your final task front and centre throughout your planning will help you ensure that you are using tutorial time as effectively and efficiently as possible.

What skills and what knowledge are most important?

The next step in backwards planning is to identify what 3-4 things you want your pupils to ***understand*** in terms of subject knowledge and what 3-4 things pupils should ***be able to do*** in terms of academic skills to be successful on their final assignment.

As you are the subject expert, you know what knowledge is most essential for pupils to know. The mark scheme in the handbook template, will be helpful in thinking about what academic skills you might want pupils to be able to do by the end of the course. You should also think about what mathematical or problem-solving skills pupils will to understand and be able to do. Here's an example to get you started:

Example – Final assignment research question

Final assignment title: To what extent do you agree that operational error is more important than design to cipher security?

Consider including the following information in your essay:

- Kerchoff's Theorem
- Numbers of possible combinations
- Historical examples of codes being broken
- Suggest a design for your own cipher and consider why you have designed it that way and how it could be improved.

Understand:	**Be able to do:**
❑ How ciphers are made more secure and how they are broken ❑ A selection of historical ciphers and their operational flaws ❑ The mathematical theories behind ciphers and how to apply them	❑ Use of correct mathematical language ❑ Apply mathematical reasoning to support analysis and explain the significance ❑ Assess different points of view and establish a clear point of view

Use the two sections below to think about what you want pupils to understand and do by the end of the course **in their written work.** For the subject knowledge, these should be 3-4 of the most important points of your course topic. For the academic skills, take a look at the mark scheme and see which 3-4 skills are most central to success in your final assignment question.

Final assignment title:

Understand:	**Be able to do:**

Do feel free to revise your final assignment question if you think it does not allow pupils show what they understand and can do as effectively as first thought. It is worth consistently referring to these overall aims of your course as they should inform everything you plan going forward.

Example – Final assignment problem set

You should repeat this activity with your intended **problem set**. There is an example to support with this.

Problem Set (accompanies the written component above)

Your answer must include

- Working out
- Labelled diagrams as necessary
- References when used

Question 1: 'E is the most common letter in the English language' ***(5 marks)***

P(vowel)=

Question 2: Use frequency analysis on the above cipher text to find the key of this shift cipher ***(15 marks)***

VULDH FAVZV SCLHU LUJYF WALKT LZZHN LPMDL RUVDP AZSHU NBHNL PZAVM PUKHK PMMLY LUAWS HPUAL EAVMA OLZHT LSHUN BHNLS VUNLU VBNOA VMPSS VULZO LLAVY ZVHUK AOLUD LJVBU AAOLV JJBYY LUJLZ VMLHJ OSLAA LYDLJ HSSAO LTVZA MYLXB LUASF VJJBY YPUNS LAALY AOLMP YZAAO LULEA TVZAV JJBYY PUNSL AALYA OLZLJ VUKAO LMVSS VDPUN TVZAV JJBYY PUNSL AALYA OLAOP YKHUK ZVVUB UAPSD LHJJV BUAMV YHSSA OLKPM MLYLU ASLAA LYZPU AOLWS HPUAL EAZHT WSLAO LUDLS VVRHA AOLJP WOLYA LEADL DHUAA VZVSC LHUKD LHSZV JSHZZ PMFPA ZZFTI VSZDL MPUKA OLTVZ AVJJB YYPUN ZFTIV SHUKJ OHUNL PAAVA OLMVY TVMAO LMPYZ ASLAA LYVMA OLWSH PUALE AZHTW SLAOL ULEAT VZAJV TTVUZ FTIVS PZJOH UNLKA VAOLM VYTVM AOLZL JVUKS LAALY HUKAO LMVSS VDPUN TVZAJ VTTVU ZFTIV SPZJO HUNLK AVAOL MVYTV MAOLA OPYKS LAALY HUKZV VUBUA PSDLH JJVBU AMVYH SSZFT IVSZV MAOLJ YFWAV NYHTD LDHUA AVZVS CL

Question 3: A message you have intercepted encrypted using the Vigenère cipher has a repeated pattern 20 letters apart. What are the possible key lengths used? Justify which key lengths are the most likely and how you would test your theory using the intercepted message. ***(6 marks)***

Question 4: Write the below permutation in cycle notation ***(4 marks)***

$$\beta = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 4 & 5 & 6 & 3 & 7 & 2 & 8 \end{pmatrix}$$

Question 5: An adapted Enigma machine has 20 letters with a plug board that chooses 2 letters to exchange. How many possible ways are there to choose these 2 letters? ***(6 marks)***

Question 6: The same adapted enigma machine as above has 5 rotors to place in 3 slots. How many possible ground settings are there for this machine? ***(13 marks)***

Settings			Total number of Ground settings:
Rotor	Plugboard setting	Initial rotor setting	

Understand (mathematical skills)

- ❑ How to calculate probabilities
- ❑ How to calculate permutations
- ❑ Convert permutations to table notations

Be able to do:

- ❑ Complete frequency analysis using probabilities
- ❑ Generate varied expressions of permutations
- ❑ Clearly display calculations/workings out

Use the two sections below to think about what you want pupils to understand and do by the end of the course. For the subject knowledge, these should be 1-2 of the most important calculation concepts behind the problem set. For the academic skills, take a look at the mark scheme and see which 1-2 skills are most central to success in your final assignment question.

Problem Set:	
Understand:	**Be able to do:**

and Check

- Does your final assignment allow pupils to show that **they understand and can do** the points listed above?
- Will the final assignment challenge pupils academically?
- Are both the final assignment and the aims of the course written above in pupil friendly language (i.e. free of complex subject vocabulary) so that they could be shared directly with pupils?
- In your problem set planning, have you determined what operational knowledge pupils need to be successful and does it include a mix of accessible questions and questions that will stretch pupils?
- **Top Tip:** Rope in a family member, flatmate or partner who is not doing a PhD and share the final assignment question and aims with them. If they have a sense of where they might start with the question (even if it's only what information they may need) then you're off to a good start!

Section F: Baseline Assignment

What is a baseline assignment for?

Your first tutorial should contain an introduction to some of the key foundational concepts of your course. Your baseline assignment should therefore test some of the concepts covered in tutorial 1, and assess the extent to which pupils understand the concepts and have the skills that will be used and tested throughout the programme.

You must include a problem set in the baseline assignment, if you are including one in the final assignment. With the problem set part of the baseline assignment, it is important that the pupils can access part of it. If you give the pupils just one question to answer, that includes the same level of understanding you expect in the final assignment, then pupils will not want to attempt it. Ensure that the problems set will allow you to assess foundational knowledge, including some straightforward questions, as well as some more challenging questions that gives pupils the opportunity to attempt what will be expected of them later in the course.

Key pointers for designing baseline assignments:

- Good STEM baseline assignments allow pupils to access the whole mark scheme, as well as allowing the tutor to understand the student's prior knowledge. Your baseline assignment should also allow pupils to develop the skills you will be assessing in the final assignment.
- The baseline assignment is marked according to the same mark scheme as the final assignment
- As the baseline provides an indication of pupils' knowledge and skills at the start of the programme and therefore we expect baseline marks to be relatively low.
- It should be written in a way that is approachable to pupils; you want to test **what they know and can do now, not assess how well they can determine what you might want them to discuss or to assess how well they can interpret a task.** Like the final assignment, pupils tend to produce a more thorough and confident piece of work if this is first broken down into parts, detailing what is expected in the baseline assignment.
- It should allow pupils to use knowledge learnt in Tutorial 1 in a way that mirrors the final assignment in the sense that it is **testing the same skills**. Importantly, it does not need to assess all key subject knowledge as this is what they will learn with you throughout the course.
- It is important to allow pupils to demonstrate all the skills in the mark scheme in the written task.
- The written assignment can often provide the basis for the pupil's final assignment introduction – this can be a good way of considering what to set as your baseline assignment.

Baseline assignment – a measure of progress

Remember, the baseline assignment is used as a measure of pupils' progress throughout The Scholars Programme. The baselines assignments should be marked according to the same mark scheme, and to the same standard, as the final assignment. We therefore expect baseline assignments to be relatively low. If you find yourself giving multiple 1st class marks for your baseline assignment, consider if this pupil is already performing to an excellent standard at the key stage above.

Backwards Planning for the baseline assignment

Having designed your final assignment and determined the most vital academic skills and subject knowledge for success in the final assignment, the baseline assignment allows you to assess where pupils are starting from. Therefore, it is important that you continue the backwards planning process to ensure that you are starting from the most useful point to support your pupils towards the final assignment.

Example – Baseline assignment research question

Final assignment title: To what extent do you agree that operational error is more important than design to cipher security?

Consider including the following information in your essay:

- Kerchoff's Theorem
- Numbers of possible combinations
- Historical examples of codes being broken
- Suggest a design for your own cipher and consider why you have designed it that way and how it could be improved.

Understand:

- ❑ **How ciphers are made more secure and how they are broken**
- ❑ A selection of historical ciphers and their operational flaws
- ❑ **The mathematical theories behind ciphers and how to apply them**

Be able to do:

- ❑ **Use of correct mathematical language**
- ❑ **Apply mathematical reasoning to support analysis and explain the significance**
- ❑ **Assess different points of view and establish a clear point of view**

Baseline assignment title: How secure is a Caesar Cipher?

Consider including the following information:

- Why is frequency analysis important?
- What can we learn from frequency analysis?
- What can we do to stop frequency analysis in breaking codes?

***Bolded text can be assessed in both the baseline and final assignment**

Example – Baseline assignment problem set

Final assignment problem set: Please refer to previous section

Understand (mathematical skills)

- ❑ **How to calculate probabilities**
- ❑ How to calculate permutations
- ❑ Convert permutations to table notations

Be able to do:

- ❑ **Complete frequency analysis using probabilities**
- ❑ **Clearly display calculations and workings out**
- ❑ Generate varied expressions of permutations

Baseline assignment problem set:

Question 1: Cipher the below plaintext using the Caesar cipher. ***(4 marks)***

'Caesar sent all of his messages in code to keep them secure'

Question 2: Decipher the below ciphertext using the Caesar cipher ***(6 marks)***

FUBSW RJUDS KBLVW KHVWX GBRIF RGHDQ GFRGH EUHDN LQJ

Question 3 The below cipher text has been encrypted using a shift cipher not equal to 3. ***(10 marks)***

i. Use frequency analysis on the below cipher text to find the frequency of G, O and M.
ii. Which of these three letters is most likely to be a vowel? Why?

UWKSQ VOJQZ LALWV BLWWV MBPQV OJCBU ISMUC AQKNW ZCABW MVRWG BPMGL WVBMI BCXXM WXTMA OIZLM VALWV BVMAB QVKWZ VKZQJ ABPMG LWVBL WWVMB PQVOJ CBAQV OBPMQ ZPMIZ BAWCB NWZCA BPIBA EPGQB AIAQV BWSQT TIUWK SQVOJ QZL

Question 4: Design a shift cipher with key>3. Complete the below table for the cipher text. ***(4 marks)***

Key =

Plaintext	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**	**m**	**n**	**o**	**p**	**q**	**r**	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**
Ciphertext																										

Question 5: Calculate the below equivalences ***(8 marks)***

30 mod 26 ≡ 30 mod 12 ≡ 30 mod 5 ≡

Question 6 The below cipher text has been encrypted using a shift cipher not equal to 3. ***(18 Marks)***

CSHDI COMYXNC. DRKDC RYG VYXQ GOBO BOAESBON DY CDKXN YX YEB WODKV MSBMVOC LOPYBO DRO CYEXN YP K QYXQ BOVOKCOC EC. CDOZ YPP LOPYBO DRO WSXEDO SC EZ KXN VKXN WSXOC LVYG IYEB VOQC YPP. CSHDI COMYXNC DY DKUO SX DRO BSXQ YP DBSLEDOC KVV OAESNSCDKXD PBYW DRO MYBXEMYZSK K QSKXD QYVNOX RYBX CRKZON VSUO K MYXO GSDR K MEBFON DKSV DRO WYEDR YP GRSMR SC KD VOKCD DGOXDI POOD RSQR CZSVVSXQ YFOB GSDR DRO DRSXQC DRKD GSVV QSFO EC VSPO ROBO SX DRO KBOXK. PYYN MYXDKSXOBC YP GKDOB GOKZYXC WONSMSXO QKBWOXDC PSBO CDKBDOBC. CDBOGX KBYEXN DRO MYBXEMYZSK KBO YDROB CEZZVSOC DROSB FKVEO NOMBOKCSXQ DRO PKBDROB DROI KBO PBYW DRO RYBX. PYB SXCDKXMO, YXVI K POG CDOZC PBYW WI POOD VSOC K DRBOO-PYYD CAEKBO YP ZVKCDSM. MOBDKSXVI SD MYEVN LO YP CYWO ECO SX K NYGXZYEB. LED DROBO SX DRO WYEDR S MKX COO K DOXD ZKMU DRKD GYEVN ZBYDOMD PBYW KVWYCD KXI CYBD YP GOKDROB. SP S RKN DRO QEDC DY QY SX KXN PSQRD PYB SD KQKSXCD DRO YDROB DGOXDI-DRBOO DBSLEDOC. GRSMR S RKFO LOOX SXCDBEMDON XYD DY NY.

Using frequency analysis and the characteristic of the ciphertext, find which cipher text letter represents 'e' and the key.

Key pointers for designing baseline assignments:

- The baseline assignment is marked according to the same mark scheme as the final assignment and with the written task and the problem set both out of 100 in total.
- The baseline provides an indication of pupils' knowledge and skills at the start of the programme and therefore we expect baseline marks to be relatively low.
- It is important to allow pupils to demonstrate all three of the skills in the mark scheme in the written task. The easiest way to do this is to provide a question for the pupils to answer in 150-250 words.
- The written assignment can often provide the basis for the pupil's final assignment introduction – this can be a good way of considering what to set as your baseline assignment.
- When writing the problem set, ensure that it includes some questions that pupils will be able to do and understand, as well some challenging questions that give an insight into what the pupils will study later on – this should excite not scare them!

Baseline assignment – a measure of progress

Remember, the baseline assignment is used as a measure of pupils' progress throughout The Scholars Programme. The baselines assignments should be marked according to the same mark scheme, and to the same standard, as the final assignment. We therefore expect baseline assignments to be relatively low. If you find yourself giving multiple 1st class marks for your baseline assignment, consider if this pupil is already performing to an excellent standard at the key stage above.

and Check:

Revisit your baseline assignment and determine what aspects of the question will allow you to test the key skills you highlighted previously. Have you written an assignment that lets pupils show off the skills they have and the knowledge they have gained from tutorial 1? Are the skills pupils are using directly relevant to the final assignment? The chart below uses the previous example to help you approach these questions:

For the final assignment, pupils will need…			
Skills (your "be able to do")	**Where I can assess this in the baseline.**	**Content (your "understand")**	**Where I can assess this in the baseline.**
Use of correct mathematical language	Pupils' answers to the questions will give them the opportunity to use accurate mathematical language	How ciphers are made more secure and how they are broken	Pupils will learn further examples in the course, but in the baseline assignment they are asked to determine how secure the Caesar cipher is, which will also need a consideration of how it can be broken
Apply mathematical reasoning to support analysis and explain the significance	In assessing the Caesar cipher, pupils will apply the mathematical concept of X to formulate their answer. Top answers will clearly demonstrate how the maths concept supports their answer	The mathematical theories behind ciphers and how to apply them	As above, pupils will learn further examples in the course, but in the baseline assignment they are asked to determine how secure the Caesar cipher, which will allow them to discuss the maths behind breaking it
Assess different points of view and establish a clear point of view	The question asks pupils to take a clear perspective		
For my final assignment, pupils will need…			

Examples of problem set baseline assignments

Below are some examples of STEM baseline assignments that work well and allow pupils to access the whole mark scheme, as well as allowing the tutor to understand the student's prior knowledge. Your baseline assignment should also allow pupils to develop the skills you will be assessing in the final assignment. For the written part of the final assignment, we would recommend for KS4 that this is ~200-250 words. The examples below are the baseline assignments associated with the example final assignments

Example baseline assignment 1

Baseline assignment problem set (50 Marks)

1. If light hits a mirror at an angle of 20 degrees, at what angle will it reflect from the mirror?
2. Does absorption depend on the colour of light? If so, how?
3. Does scattering depend on the colour of light? If so, how?
4. Can light focus to an infinitely small spot size? Why or why not?
5. Define the terms **amplitude** and **phase** in terms of how they describe a wave. You may use a drawing to help support your response.
6. Define the terms **resolution** and **contrast**.
7. True or False: Using ray tracing, I can determine the magnification of a lens. Explain your answer.
8. Solve the following equation for x:

$$X = \sin\frac{\pi}{2}$$

Baseline research question (50 Marks)

What sources of contrast exist in the body to generate images? (200 words)

- First, describe in general how contrast is generated in images. You may want to focus on key words discussed in class including **absorption, transmission, reflection, and scattering**. Provide at least one specific example - Don't be afraid to be creative! Think about how light can interact with different parts of the body.
- Second, use your own online research to investigate one imaging technique discussed in class. Describe briefly how it works and what the main source of contrast is. You may use the information on the next few pages to help you.

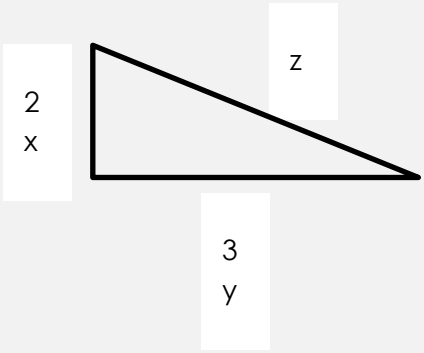
Don't forget to include a **bibliography**. A bibliography is a list of any books or websites that you used when writing your response.

Gavrielle Untracht – Seeing the Small with the Small: Designing Miniature Microscopes for Medical Imaging

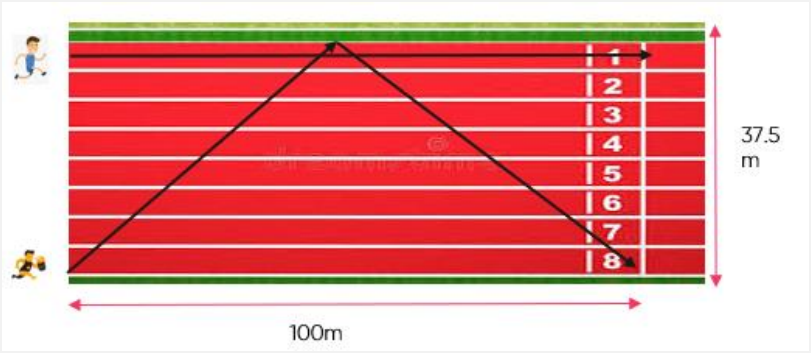
Example baseline assignment 2

Baseline assignment problem set (50 Marks)

1) See the diagram of a right angle triangle. Using pythagoras' theorem calculate the length z in terms of x and y.



2) Find x where $0.000067 = 6.7 \times 10^{x}$
3) Find y where $460000000 = 4.6 \times 10^{y}$
4) Two men are running along a 100m track. Both maintain a steady pace of 5 meters per second. The first travels in a straight line. How long will he take to complete the 100m distance?
5) The second man takes a (symmetrical) diagonal course as shown in the diagram. Calculate how far he needs to travel to complete the race. How long will it take him to complete the race?



6) I'm standing on a platform while a train slowly travels past at 10m/s. A person on the train is walking up the carriage towards the front of the train at 1m/s. How fast is the person moving relative to me?
7) The person now changes direction and walks at the same speed towards the back of the train how fast are they now moving relative to me?
8) The tennis player John Isner holds the world record for the fastest ever serve at 157 miles per hour. For reasons we haven't been told he is standing on top of a train travelling at 120 miles an hour. He serves a ball from the train. In the opposite direction to the direction of travel of the train. How fast is the ball travelling relative to an observer not on the train?
9) Consider the transformation of numbers $x \rightarrow x^2$. (i.e. each number is transformed into its square). Which number is invariant (doesn't change) under this transformation? Would this transformation be symmetric under addition? Multiplication?

NB: Research question available on next page

Baseline research question (50 Marks)

Produce a short piece of writing (approximately 150-250 words) formally introducing the concept of symmetry. You should describe what is meant by both continuous and discrete symmetries and give examples (either from the tutorial or if possible further examples which you have researched or thought about yourself) including diagrams where possible. Describe examples of symmetries within physics and give a qualitative description of Noether's theorem. You might include a brief description of who Emmy Noether was (when she lived and how she came to develop her theorem).

Lauren Martin – Symmetry, Symmetry Breaking and Why the Universe Doesn't Annihilate Itself

Section G: Tutorial Outlines

Tutorials 1-4

This is the last step in the backwards planning process. You have determined where pupils need to get to (the final assignment), you have identified the key academic skills and subject knowledge they need to be successful, and you have the ability to determine where pupils are starting from (the baseline assignment). As mentioned previously, **Tutorials 1-4** will allow you to introduce the core concepts of your course and engage pupils in thinking critically about these topics.

When planning your tutorials, you should be able to directly connect how the purpose, key questions/concepts/case studies and homework assignments help pupils build the skills and knowledge necessary for their final assignment.

The following questions and tutorial outline examples will guide you through the process of designing each tutorial. You do not need to have full sessions and activities planned. The Course Design Template will ask you to answer the questions below and you will receive feedback on these from a qualified teacher or subject expert within our team.

When planning each tutorial, you should remember the final assignment that your pupils will be working towards and consider how each tutorial will support them to complete it.

What is the main topic or concept covered?	• Think about the main topic or concept for the tutorial. How does it fit the overall outcomes of the course and support pupils to complete the final assignment? • Have you considered how you have spread the course content across the tutorials? • What is the key message in the tutorial that you want them to remember? • Is this focused enough for pupils to cover in one tutorial? Remember, you should aim to cover **no more than one or two concepts** in each tutorial. With a problem set, it will be important to check that pupils are developing skills and knowledge relevant to both the written and problem set elements of the course.
What are the key questions and learning outcomes?	• What will the main learning outcomes be? For example, what work will pupils produce? What discussions will they have? • What will pupils know about/be able to do at the end that they could not at the start? • How will you know that pupils have achieved these outcomes by the end of the tutorial? • You should consider including a **hinge-point question**, which is a question designed to help you check whether pupils have understood a core concept. More information can be found in Appendix 3.
What case studies, readings and activities	• Think about what content the pupils will need to cover in the tutorial to meet your overall aim.

will be included in this tutorial?	• Consider the questions that you will use to guide the tutorial and how you will use these to assess pupil understanding, including how their responses to their questions will guide the next stages of learning. • Do you need to reconsider the amount in other tutorials to leave space to prepare for the final assignment? • Be as specific as you can regarding the content that your pupils will explore in this tutorial, giving an example of activity if you have one in mind.
What are the key terms/words?	• Learning the definition of key terms will help pupils learn new concepts and access the language of your subject. • Keep the amount of new words to a manageable amount (no more than three) and test pupils on them regularly. • Most tutorials will introduce new vocabulary; pupils should be clear about what new keywords mean and be confident in using these is unfamiliar situations. • Defining your key terms will help you think about how to introduce them and what activities you can use to help ensure that the pupils are confident in their use of new vocabulary.
What homework assignment will you set?	• The homework assignment you set each tutorial serves three purposes: to review your past tutorial and to prepare for the following tutorial. It also allows you to check pupils' progress towards the key academic skills and knowledge vital for the final assignment. • The homework assignment should recap the key material set in the tutorial but also provide an introduction and basis for the discussions and activities that you plan for the following week. • Depending on your course content and final questions, the homework assignments could be structured to build up to the final assignment by dealing with a different aspect of it each week.
TUTORIAL 5 ONLY: What form will the DRAFT ASSIGNMENT take?	• You must set a draft assignment at the end of Tutorial 5. • This could be an introduction, a first paragraph and a plan, but it should be substantial enough to constitute at least half of their final assignment. • You will give one-to-one feedback in Tutorial 6

When outlining your tutorials, ensure you include resources and plan the following:

- Check pupils' understanding
- Let pupils participate – can you build in pupil-led discussion?
- Practise and build key academic skills
- Help pupils develop the skills of analysis, evaluation and problem solving

It is important to provide ample opportunities for pupils to **apply and use** the knowledge they've gained through activities or strategies like the ones outlined above. In university this often takes the form of writing notes or reading a journal article, and while these will be useful skills for your pupils to develop, they will also need interactive opportunities to apply the knowledge they've gained. You

should plan carefully for activities that allow pupils to explore their thoughts and ideas, such as applying new information to a scenario, coordinating a debate or conducting a discussion in pairs or as a group. For ideas on how to build discussion and activities into your tutorial, see Appendix 2.

Top tip

Experiments are best avoided in tutorials. Sometimes it is nice to be able to illustrate a concept with props or data and this is encouraged – this usually works really well in increasing pupil participation and engagement. However, don't turn the whole tutorial into an experiment – it's often more productive to support pupils to analyse existing data e.g. images etc, than to try to generate new data.

For STEM subjects in particular, you may need to cover some complex concepts in order for pupils to access some of the higher-order elements of your course. To ensure that topics can be grasped by students, they need to be broken down and made accessible. This can be done in a variety of ways, including using activities, metaphors, or simply breaking the concepts down into bite-sized chunks.

Metaphors and imagery – illustrate the point with something students will be familiar with. We learn by hooking new information on to pre-existing concepts. Metaphors, analogies and imagery can work really well for getting pupils to 'see' what you are explaining and to understand new ideas in relation to ones they are already familiar with. For example, using horse-racing analogy to explain electricity. The horses are the electrons, and the racetrack is the electrical circuit. Pupils can then apply this knowledge to the scientific point in question.

Activities first - Explaining a complex scientific concept can be challenging, and it's really hard to know if students have understood. By using a well-planned activity first, students can understand a concept without the jargon and complexity, and then are thinking along the right lines when the activity is explained. It's important to plan such activities well bear the following in mind:

1. Keep it simple
2. Ensure pupils are given the chance to relate this back to the topic in question.

Link it back - Explanations can be hard to follow when it's not clear how the information being given fits in to the course. You will need to facilitate this as, especially with younger pupils, students will not always be practiced in doing this themselves. Ask students to explain how new information links to information previously covered. Review previous tutorials at the beginning of a session and ask students to discuss how new information can be used in the final assignment

Break it down - Break down your explanation into its key concepts and build in an opportunity to check all pupils' understanding or for them to do an activity to apply, evaluate or analyse the information learnt. That way the explanation becomes a series of shorter ladders with platforms for pupils to pause at.

I do, we do, you do – when talking through a problem, complete the work in three steps: I do, we do, you do. Start by showing the pupils how you would model an answer, then do another similar example or two together as a group, and then set pupils on the work themselves. This will increase the pupils' confidence before they start.

A note on academic journal articles: Reading and using academic journal articles to inform one's argument is undoubtedly an important skill for students a university and can introduce complex ideas and evidence to readers. However, your pupils will be entirely new to academic literature like this and will need support from you to engage with it successfully. If you wish to include academic journal articles, you can support pupil engagement with these resources by selecting the most pertinent sections from the article, aiming for **no more than 1-2 pages in a tutorial, and 3-4 pages for homework**. You could also supplement pupils' learning by

- modelling how you would approach and engage with the first paragraph, particular how you approach unfamiliar vocabulary or complex ideas
- physically highlighting the most essential passages
- including a handful of questions that pupils can use to guide their reading.

Please avoid including an unabridged article with no specific guidance to support pupil engagement with this text, as pupils will read likely each individual word for understanding rather than having the existing skills to take any broader meaning or learning from an article.

Planning for inclusive teaching

As we work with pupils from backgrounds that are under-represented at highly selective universities, it is important to consider designing your course in a way that reflects the diversity of contributions and actors within your subject area. This also provides a unique opportunity to design a truly supra-curricular course by encouraging pupils to consider why certain ideas or viewpoints may be unfamiliar to them or to support them to view a subject from a new vantage point.

In thinking about what tutorial outcomes, aims and activities you wish to include in your course, we encourage you to select the most important and productive examples, even if they may not be the most seminal or canon examples within your discipline. Of course, there will be times when these canon sources are the most appropriate, but in planning your course, we encourage you to think critically about what voices are, or are not, included in your course and how you might prompt pupils' critical thinking about different perspectives. Increasingly, this sort of thinking is linked into calls to decolonise curricula and we have created an additional resource to support with how this relates to your subject, which you can access using the link below

Decolonising Your Course Toolkit: STEM Toolkit

(the password is the same that you used to access the training sessions online)

These toolkits were designed in collaboration with:

THE BLACK CURRICULUM

Tutorial 5

Tutorial 5 should focus on revising the concepts covered in Tutorial 1-4 as well as introducing the final assignment. For homework, pupils should complete a **draft assignment task**. As an academic essay of this length will be an entirely new task for pupils, they will benefit greatly from this dedicated time to review and prepare for the final assignment. Specifically, pupils will benefit from guidance on how to structure an academic essay, what they might want to include, support in understanding the difference between description and evaluation, the use of evidence and the importance of developing their own argument/position in relation to the final assignment. As a result, it is nearly impossible to cover new content meaningfully in this tutorial and support pupils effectively towards the final assignment, so please do consider this in your planning.

Some Revision Strategies

- **Present Day Problem/Issue** – if there is a relevant present-day situation that relates to the themes of your course, you can support pupils to revise by asking them to apply what they've learnt to this new context
- **Concept mapping** – provide pupils with a blank concept map and as them to make connections between the ideas they've learnt about
- **Adapt an activity** – activities that were productive in getting pupils to engage with new content can also be helpful in revision.
- **Character profiles** – as pupils to create "identity cards" for individuals, countries, stakeholders etc. relevant to your course which include their name, purpose or motivations and any arguments or perspectives that will be important for pupils to recall.
- **Mini-debate** – divide your tutorial group in two for a quick debate around a big question relevant to the aims of your course. After giving pupils a few minutes to plan, and clear instructions about how the debate should proceed, ask them to speak from their assigned perspective and provide evidence to support their ideas.

Suggested Draft Assignment Tasks

- **Complete an outline** – provide pupils with an outline template or structure and ask them to complete this with the points and evidence they will include in their final assignment
- **Make a start** – ask pupils to write the first 2-3 paragraphs of their final assignment and outline what the remaining paragraphs will be about
- **Break it down** – ask pupils to answer a simplified version of your final assignment question to collect and articulate their thoughts in a shortened word count. It will be important to make clear that this prompt is central to their final assignment task and will be one they'll expand and adapt for the final assignment.

Remember, referencing will also be new to pupils, so you will need to devote time in this tutorial or in earlier tutorials to introduce the purpose of referencing, explain how and what part of their essays will need a reference, and allow pupils time to practise this skill.

Tutorial 6 and 7

Tutorials 6 and 7 will be opportunities to provide pupils with feedback on their draft and final assignments. Further information about these tutorials and strategies for giving effective feedback are covered in tutor training sessions, but as these are based around feedback, the structure of these tutorials does not require any further planning for your handbook.

Section H: Homework

Homework assignments are a useful way to have pupils cover important content and prepare for the following tutorial. With all homework assignments it is crucial to find time in the tutorial to carefully explain what they need to do and to share success criteria with them. Likewise, at the start of the following tutorial, you should aim to make time to review the assignment, allowing pupils to receive feedback and reflect on what they have learned.

In order to stretch pupils, tutors may require pupils to read complex scientific literature. It is crucial that with all reading activities pupils are supported to access the material and that they have a clear purpose. Pupils should never be given a text just to read. Don't forget that pupils will not be familiar with accessing and understanding scientific literature, particularly primary research. If you would like pupils to use published research (which is a great skill to learn), it is be worth providing small sections of important papers for them and spending some time in the tutorials discussing how to get the relevant information from scientific papers. Perhaps you could consider using some figures for papers as a discussion point in this tutorial and analysing the data from the papers together in the tutorial to build up pupil's confidence.

It is also important that your homework tasks build up towards your final assignment. We recommend you vary the style of written homework tasks throughout your tutorials, for example setting some written work, some research-based work, and possibly some presentation or debate preparation.

We expect pupils to spend **no more than 30 minutes** completing their homework assignments, so please do keep this in mind when setting a task.

Ideas for written homework tasks:

- **Summaries.** Pupils write a summary of the text they have read. Set clear minimum/maximum word limits for these tasks.
- Prepare for a **debate**
- Put together a 2-3 minute **presentation** on a topic that pupils have researched related to the tutorial content
- **Data analysis** – looks at images/data and write a summary of their interpretation.
- **Creating questions.** Pupils draw up questions about the text and then pose them to other pupils. (Pupils must be able to answer their own questions).
- **Role play a scenario** – Set a homework question that asks pupils to apply key knowledge and concepts from the tutorial to a real-life scenario. For example, they may write a letter to an influential figure, write a proposal or evaluate a set of data to share their conclusions for a local authority or other influential body.
- **Please see the note on journal articles page 34**.

Section I: Course Title

The title does not have to be the same as the final assignment title, although in some cases it is the same. You may choose to phrase your title as a question, a statement or some of the specific concepts that will be studied.

Review: It can excite pupils when there are highly specialised words in the title as this is an instant indication of the university-style approach that your course will take. However, as a golden rule, the best titles are "***low access, high challenge***", in other words they indicate problems that are easy to understand, but difficult to resolve.

It can be helpful to think of your course title as similar to the title of an undergraduate module where part of the aim is to "sell" the course to students, as this will similarly get your pupils excited about the course. We encourage you to avoid considering course titles that are more similar to academic paper titles, as these are less approachable for non-academic audiences.

Examples:

- Should we build a quantum computer?
- Outwitted by an octopus
- Everything in the world is an equation
- Aches and Brains – the Neuroscience of pain
- Getting to the heart of the heart
- Could stars float in the bath?
- Superbugs – the ticking timebomb

Section J: Course Rationale

The course rationale will serve as an introduction to the course. The rationale should provide a 'hook' for the course that gets pupils excited about what they will be learning. Think of it like the abstract to your course. It should be written to be clear, succinct and easily understood by a non-specialist audience, including parents, teachers in schools, and the pupils who will be taking part in the course.

Action: Write your course rationale in the section provided. Please write in full sentences and avoid bullet points and other types of non-standard formatting. Your course rationale should be around two paragraphs and could include the following:

- A summary of the key content, ideas and debates that pupils will study through the course
- A brief explanation of how the course fits into the wider context of the field and the subject
- A summary of the key skills that pupils will develop through the course

Please note that it may also be useful to have a brief introduction to each of the tutorials.

 and Check

Once you have written your course rationale, it is worth checking the pitch of your rationale by considering the following questions:

- Does this make my topic sound exciting?
- Have I explained why this topic is important and worth studying?
- Will this be understood by parents, non-specialist teachers and the pupils themselves?

It would be worth asking someone who is not doing a PhD to read through your course rationale and get their opinions on the questions above.

Example

Mathematics is more than just arithmetic; it is used to solve the most advanced problems in the world today, as well as discover old secrets. Using probability and number theories we can discover how much we don't know just by using the information we have. Cryptography is 'the art and science of making communications unintelligible to all except the intended recipient(s)'. The need to conceal messages isn't a recent development; Caesar famously shifted each letter of his messages by three places in the alphabet to securely communicate between his generals, and the failure of Mary Queen of Scots' cipher ultimately led to her execution for treason.

This course will start by looking at famous ancient codes and how they were cracked using mathematical techniques and strategies developing pupils' mathematical problem solving skills in a real-life context. In the 3rd and 4th tutorial the pupils will be introduced to the famous Enigma machine, how it was used and how the code was broken in World War 2. The pupils will be asked to critically evaluate the complexity of this cipher and compare this to its ancient counterparts. In the final assignment, the pupils will be challenged to design a secure code and to argue why it would be secure using the theories they learned throughout the course.

Over many centuries, cryptography and cryptanalysis (code breaking) developed into a complicated discipline that is still used to this day – pupils will develop a rich understanding of the history of codebreaking in mathematics and how to use their problem solving skills to tackle complex mathematical problems. – **Cracking the Code: Did Maths Win the War?**

Appendices
Appendix 1: Mark Scheme

This is the **standard 13-16 STEM problem -set mark scheme**. In this case, the problem-set mark scheme should be used for 50% of the overall mark to assess the research task.

	Subject Knowledge	Critical Thinking	Written Communication
1st	The work shows a depth of knowledge and understanding of key concepts and scientific or mathematical methods, through engaging with relevant sources. Knowledge is used to build and support highly effective scientific/mathematical arguments and explanations.	Analyses key scientific or mathematical evidence, arguments, and reasoning. Interprets meaning and makes connections. Identifies and critically evaluates key scientific or mathematical arguments and evidence, deciding on their credibility, strength, and relative significance, drawing convincing conclusions.	The work has a coherent flow and is well structured. The writing style is appropriate; scientific or mathematic language and key scientific or mathematical terms are used accurately and effectively to support the arguments and explanations made. There are no, or very few, errors in spelling or grammar. Consistent referencing, appropriate paragraphing and use of correctly labelled tables and graphs matching the style taught in the course.
2:1	The work shows an understanding of key concepts and scientific and mathematic methods, drawing on relevant sources. Knowledge is used to build and support effective scientific or mathematical arguments and explanations.	Analyses relevant scientific or mathematic evidence, arguments, and reasoning. Identifies and critically evaluates relevant scientific or mathematical arguments and evidence, deciding on their credibility and strength, drawing reasonable conclusions. Shows some understanding of the relative value of evidence and arguments.	The work is well-structured. The writing style is appropriate; scientific or mathematical language and key terms are used correctly. There are few errors in spelling or grammar. Mostly consistent referencing and use of tables and figures; matching the style taught in the course.
2:2	The work shows an understanding of key concepts and scientific or mathematical methods, with no major misconceptions. Beginning to apply this knowledge to build and support effective scientific or mathematic arguments and explanations.	Identifies and uses basic scientific or mathematic evidence, arguments, and reasoning. Showing some understanding of the quality of scientific or mathematic arguments and evidence. Not yet showing understanding of the relative value of evidence and arguments.	The work has some structure. The writing style can sometimes be informal; occasionally scientific or mathematic language and key terms are not used when it would be appropriate to do so. There are some errors in grammar and spelling do not get in the way of communicating the content. Referencing has some consistency; matching the style taught in the course Limited use of tables and graphs.
3rd	Shows a developing understanding of key concepts and scientific or mathematical methods, with some misconceptions. Does not yet apply this knowledge to build and support scientific or mathematic arguments and explanations.	Beginning to analyse scientific or mathematic evidence, arguments, and reasoning. Describes evidence and arguments, while not yet evaluating them.	The grammar, spelling, style, and structure of the work need improving in order to communicate ideas to the reader. Scientific or mathematic language, key terms and references are not always used correctly. Limited, or no use of tables and graphs.

Appendix 2: Tutorial activities

This section will hopefully give you plenty of ideas for activities that could be included in your tutorials. You are not expected to produce a final and comprehensive list of activities for each tutorial plan for us to check, but when putting together your course handbook, thought should be given to which activities will be best suited to help your pupils meet each objective.

Starter activities

Starter activities are short, sharp activities delivered at the beginning of the tutorial to grab the pupils' interest and to get them thinking about the topic or concept that will be covered in the tutorial. In some cases, this might mean using them to recap the key learning points from the previous tutorial or to review the homework assignment they have just completed. Overall, starter activities are an effective way to create a purposeful learning environment from the moment pupils walk through the door.

The activities listed below are suggestions for starter activities but are by no means an exhaustive list and tutors are encouraged to think creatively! The activities below could also be adapted to be used to check for learning at any point throughout the tutorial. Indeed, tutors could return to the starter activity at the end of the tutorial to check to see how pupils' initial ideas had changed.

Starter Activities

Odd one out. Pupils are given a group of words and/or pictures and have to justify which is the odd one out based on what they have been studying.

What's the question? Tutor gives an answer, pupils write a list of questions that could be answered by the answer given.

What questions do you want to ask? Based on the content of the forthcoming tutorial (or previous learning), pupils write a list of questions that they would like to have answered.

Peer assessment of homework. Pupils assess the homework of their peers and give feedback.

What is being said? Tutor shows a picture and pupils write down what they think is being said by the people in the picture.

Ridiculous arguments. Tutor puts forward a ridiculous argument (e.g. all 5 year olds should be allowed to drive cars) and pupils try to justify this argument.

1 minute. Pupils try to summarise a topic in 60 seconds.

Picture. Tutor shows pupils a picture and they describe what they think happened before/after the picture was taken.

Hot seating. One pupil is chosen, the tutor and other pupils to ask the pupil in the hot seat questions.

Questions and post-it notes. Tutor writes a number of questions on big paper, all pupils given post-it notes to use to answer the questions on the paper.

Describe and draw. Two pupils sit back to back, one of the pupils is given an image and they have to describe it to the other pupil, this pupil then draws what the first pupil is describing.

Picture analogy. Tutor shows a random picture and the pupils to explain why this is an analogy for what they are studying.

The most difficult question. Tutor sets 3-5 different questions, pupils choose one and answer it as best they can.

Mr Wrong. Tutors write a number of statements, pupils say which ones are wrong and justify why.

Keyword Activities

Taboo. One pupil describes a keyword without using it and other pupils guess what the word is. (This is a good activity for reviewing complex concepts and content learned in previous tutorials.)

Match the definition. Pupils match keywords to definitions.

Pictionary. Tutor gives a keyword and pupils draw a picture to represent this. Alternatively, pupils draw something to represent a keyword and other pupils guess the keyword.

10 words. Pupils write down 10 keywords on bits of paper. Pupils choose two of these words and describe the relationship between them.

My word. One pupil is given (or chooses) a keyword, they point at another pupil who must then give the definition of the keyword, this pupil then gets to choose the next keyword and pupil.

A-Z of the topic. Pupils try to write keywords for the topic using all the letters in the alphabet.

Splat. Tutor writes ten keywords on a large piece of paper and then chooses two pupils who stand in front of the whiteboard. Tutor then reads out the definition and the first pupil to tap the correct key word with their hand wins.

Discussion activities

Discussion activities are an excellent opportunity for pupils to exchange ideas, to challenge each other and to help formulate their own views and arguments. Indeed, it is an integral part of small group tutorial style learning. While pupils might be eager to participate in the tutorial and to voice their views, they may not always have the skills required to interact in high level discussion without support or scaffolding. Therefore, tutors initially may have to provide structure for discussions and may have to avoid asking pupils to discuss without first having time to think through and prepare.

The following tips and suggested activities give some suggestions to help tutors plan for effective tutorial discussions:

Discussion top-tips

1	Create a suitable environment for discussion. Think about how you set up the chairs, position yourself and where you stand.
2	Establish an explicit culture of respect and participation early on. Make it clear in your expectations that all pupils will need to contribute and listen to each other.
3	Ensure that every discussion has a clear purpose and that this is clearly shared with the pupils before the discussion begins.
4	Give clear instructions and expectations about how you want the discussion to take place.
5	Ensure the pupils are prepared for the discussion. Allow them thinking time; for example, a short written activity, quiz or reading before the discussion.
6	Be creative! Discussion does not always need to be verbal. Think about using 'silent debates', annotating and responding to comments on pictures as a form of preparation for a verbal discussion.
7	Don't allow pupils to contribute unsupported ideas. Challenge pupils to develop their answers. If necessary, return to pupils later.
8	Make yourself the facilitator and not the lead in the discussion. Deflect questions to other pupils to respond to and encourage pupils to talk to each other and not at you.
9	Don't be afraid of silence! Allow pupils time to think and respond to each other rather than offering your thoughts and feedback straight away. Think about the amount of wait time you are giving.
10	Encourage pupils to respond to the previous comment rather than suggest ideas in isolation.

Think, pair, share. After posing a question, give pupils a minute to think of their response in silence, then get them to share their idea with the person next to them, then ask the pairs of pupils to feedback their answers to the rest of the group.

Simultaneous round robin. The tutor poses a question, all pupils write down what they think. After a set amount of time, pupils pass on their thoughts to the next pupil for them to build on and develop.

Snowballing. First, pupils have to individually produce an answer to a question. They then share it with a partner and turn their two answers into one agreed upon answer. The pair then joins up with another pair and repeats the process. This way, four answers are synthesised into one. **For example, pupils decide on the three most significant historical events. Pupils pair up, discuss and synthesise their 6 ideas down to 3. Two pairs join to make four pairs and repeat the process again.**

Jigsawing. The tutor divides pupils into pairs. The pairs are given the same picture/text/problem. The tutor gives each pair a *different* question or focus to analyse the picture/text/problem. Next, the tutor allocates pupils into two new groups, ensuring that the pupils originally paired together are in different groups. The pupils in the new group will have approached the picture/text/problem from a different perspective. The tutor then poses a new question (or questions) for pupils to discuss and answer.

Value continuum. You can use this activity to get pupils to respond to a thought provoking statement by saying to what extent they agree with it. There are a number of ways this can be used: pupils could be asked to come and stand at the point on the continuum (e.g. an imaginary line from one wall to another) that represents their individual opinion. Alternatively, they could first be asked to discuss a statement in groups and then one of the groups comes up to the front and places their marker somewhere along the line, explaining the position their group have taken as they do so. This is an excellent format for comparing responses to different questions and finding out contradictions in their thinking.

Circle of voices. You can use this method to get pupils to feedback on homework readings at the beginning of the tutorial. Pupils form circles of four or five. Tutors give groups a topic and allow them a few minutes to organise their thoughts on it. Then the discussion begins, with each pupil having up to one minute (or choose a different length) of uninterrupted time to speak. During this time, no one else is allowed to say anything. After everyone has spoken once, open the floor within the sub-group for general discussion. Tutors should specify that pupils should only build on what someone else has said, not on their own ideas.

Appendix 3: Further reading

Knowledge vs skills

Blog-posts by classroom teachers on the question of the knowledge/skills dichotomy:

- David Didau http://www.learningspy.co.uk/learning/know-oh-hang-know/
- Joe Kirby http://pragmaticreform.wordpress.com/2013/06/20/double-helix/
- Andrew Old http://teachingbattleground.wordpress.com/2013/07/13/weasel-words-3-skills/

Depth vs breadth

On memorising and learning: Kris Boulton

http://tothereal.wordpress.com/2013/10/28/does-memorisation-get-in-the-way-of-learning-part-1/

Hinge point questions

Reflections on formulating HPQs: Harry Fletcher-Wood

http://improvingteaching.co.uk/2013/08/17/do-they-understand-this-well-enough-to-move-on-introducing-hinge-questions/

Toolkit for asking effective questions: Alex Quigley

http://www.huntingenglish.com/tag/questioning/

Multiple choice questions

The research behind MPQs: Daisy Christodoulou

http://thewingtoheaven.wordpress.com/2013/10/30/research-on-multiple-choice-questions/

Key principles: Joe Kirby http://pragmaticreform.wordpress.com/2014/04/12/mcqdesign/

SOLO taxonomy for checking understanding

Reflections on the use of SOLO in assessing pupil responses: Laura McInerney

http://www.lkmco.org/article/ecology-classroom-applying-maslowas-hierarchy-bloomas-taxonomy-and-solo-03092012

Key words and teaching academic language

5 blog posts on teaching academic discourse and language-based pedagogy: Lee Donaghy
http://whatslanguagedoinghere.wordpress.com/2013/03/

Discussion activities

An adaptation of Socratic methods from the USA: Harkness Method
http://www.exeter.edu/admissions/109_1220.aspx

And a teacher's response: http://reallybigyear.wordpress.com/2013/03/27/teaching-science-using-the-harkness-method

Appendix 4: What images can I include in my handbook?

Selecting your images

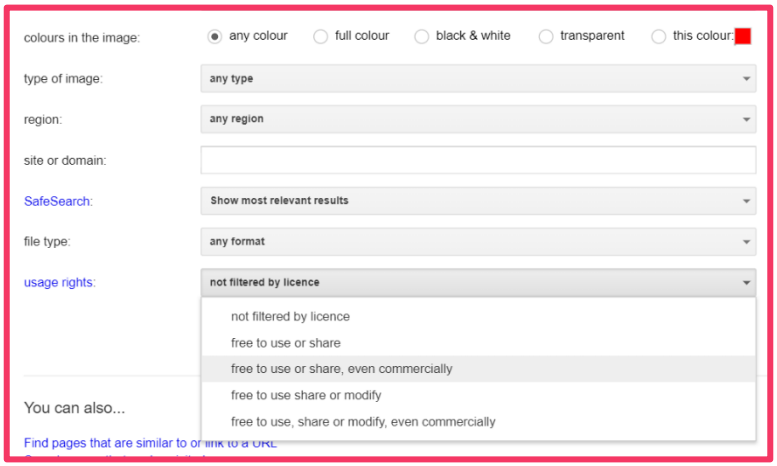
You should use public domain images in your handbook. All images on the following sites are free to use:

- Wikipedia
- Pixabay.com
- Unsplash.com
- Wellcomeimages.org (excellent for Science and Arts!)

Using advanced searches in Google

When you do a Google search, you can filter your results to find sources which you have permission to use and share.

1. Go to Google Advanced Image Search
2. In the "all these words" box type the key words for the images you want to find
3. In the "Usage rights" section, use the drop-down box and select the 'free to use or share, even commercially' option, and then 'Search'



Quotes and Extracts

The final thing to remember is quotes and extracts (e.g. from scientific literature) need to be properly referenced at the back of your handbook.

You may also be able to include some of your own data or images in your course handbook – this is often a really nice resource to use to allow pupils to engage with the concept of research.

Appendix 5: School curriculum resources

The content of your tutorial should be tailored to your research so that the pupils are learning about something beyond the curriculum and have the opportunity to experience university style learning. Therefore, we do not offer guidance on the content that your programme should include, however you can use the information in this appendix to give you an idea of the level of the work you should be setting.

Remember, pupils on The Scholars Programme should be stretched and challenged to work at a key stage above their current learning level. Specific curricular guidance depends on the location of your placement school.

- For pupils in year 9-10 pupils in **England and Wales** the current learning level is GCSE standard and pupils should be stretched and challenged to A-level
  For pupils in **Scotland** in S2-4, the current learning level is National 4 and 5 and pupils should be stretched and challenged to Higher and Advanced Highers
  For pupils in **Northern Ireland** the current learning level is GCSE standard and pupils should be stretched and challenged to A level

Below, you can access the curriculum that will be most relevant to your planning. The learning standards and curriculums give examples of the type of content and skills pupils should be demonstrating at the pupils' current learning level, and at the level at which your course should be pitched and should provide you with an idea of the level of the work you should be setting. It is important not to assume prior knowledge of the pupils based on these examples but to use them in conjunction with the skills descriptions in the mark scheme. In your course, you should include a task that allows you to check for pupils understanding of any concepts or processes they may have covered in previous lessons. The curriculums are here to help ensure that you pitch your course at an appropriate level that is both accessible and challenging.

It is important to note that these documents contain a lot of information, so don't be overwhelmed by the content; as pupils are learning about something beyond the curriculum, **you are not expected to be well versed in national curriculums**. Instead, use these to get a sense of your current pupils' level and feedback you receive on your course design will help you adjust your course to an appropriate pitch.

NB: These are not intended to be a template for what you should deliver – it is designed as a guide to help you pitch your programme at the appropriate level.

Appendix 5A: England and Wales

NB: GCSE qualifications are undertaken by pupils ages 14-16 and A Levels are undertaken by Post-16s. There are some differences in the way GCSEs and A-levels are administered and marked between the two nations and some qualifications offered in England are not offered in Wales and vice versa.

Subject	Resources and Details
General Science	Combined Science (includes biology and chemistry) GCSE Subject Content here Single Science (includes biology, chemistry, and physics) GCSE Subject Content here Science (includes biology, chemistry, physics and psychology) A Level Subject Content here
Maths	Mathematics • GCSE Subject Content here • Maths A Level Subject Content here • Further Maths A Level Subject Content here Statistics • GCSE Subject Content here • A Level Subject Content here
Engineering	GCSE Subject Content here No A Level Subject Content
Computer Science	GCSE Subject Content here A Level Subject Content here
Environmental Science	No GCSE Subject Content A Level Subject Content here
General Lists of Other Specifications	GCSE Subject Content here A Level Subject Content here Qualifications Wales here

Appendix 5B: Scotland

NB: For STEM subjects, the National 3 and 4 curriculums are mostly embodied in the Curriculum for Excellence Benchmarks, which focuses on the key skills pupils will be developing. National 5 (the general level of stretch for S3 pupils) and Higher (the general level of stretch for S4 pupils) course specifications have more details on specific content and key skills learnt in more specialised topics.

Subject	Resources and Details
Curriculum for Excellence	Numeracy and Mathematics – pages 32-53 Sciences – pages 25-46
Biology	National 5 Course Specification – pages 2-13 Higher Course Specification – pages 2-20
Chemistry	National 5 Course Specification – pages 2-18 Higher Course Specification – pages 2-26
Mathematics	National 5 Course Specification – pages 2-10 Higher Course Specification – pages 2-9
Physics	National 5 Course Specification – pages 2-15 Higher Course Specification – pages 2-20
Engineering Science	National 5 Course Specification – pages 2-7 Higher Course Specification – pages 2- 7
Computer Science	National 5 Course Specification – pages 2-10 Higher Course Specification – pages 2-14
Environmental Science	National 5 Course Specification – pages 2-18 Higher Course Specification – pages 2-29
General Lists of Other Specifications	Curriculum for Excellence Benchmarks here National Qualifications subjects here Summary of National Qualifications here

Appendix 5C: Northern Ireland

NB: GCSE qualifications are undertaken by pupils ages 14-16 and A-level qualifications are undertaken by Post-16s

Subject	Resources and Details
Key Stage 3 Curriculum	Pupils participating The Scholars Programme will be at the final year of these standards if they are 13 years old. Standards for ages 11-14 is here; Specific curriculums begin on page 30
Biology	GCSE Specification here; Section 1.1 and 3 A Level Specification here; Section 1.1 and 3
Chemistry	GCSE Specification here; Section 1.1 and 3 A Level Specification here; Section 1.1 and 3
Maths	Further Mathematics: • GCSE Specification here; Section 1.1 and 3 • A Level Specification here; Section 1.1 and 3 Mathematics: • GCSE Specification here; Section 1.1 and 3 • A Level Specification here; Section 1.1. and 3
Physics	GCSE Specification here; Section 1.1 and 3 A LEVEL Specification here; Section 1.1 and 3
Engineering	GCSE Specification here; Section 1.1 and 3 No A Level Specification
Computer Science	GCSE Specification here; Section 1.1 and 3 A Level Specification here; Section 1.1 and 3
General Science (only GCSE)	**Single Science Award:** GCSE Specification here; Section 1.1 and 3 **Double Science Award**: GCSE Specification here; Section 1.1 and 3
General Lists of Other Specifications	Other GCSE qualifications here Other A Level (post-16) here

Appendix 6: Competency Framework

The Brilliant Club has identified six skills – cognitive and non-cognitive – that we believe will be effective in developing the knowledge, skills and ambition needed to progress to a highly-selective university. We refer to these as our 'competencies'.

1	Written and verbal communication
2	Subject Knowledge
3	University Knowledge
4	Motivation and Self-Efficacy
5	Meta-cognition
6	Critical Thinking

The competency framework has been informed by academic research and consultation with our school and university partners. It focuses on outcomes that are known to be valid, reliable and measurable.

As the academic strand of The Scholars Programme, each course will explicitly develop the following skills: written communication, subject knowledge and critical thinking. As such, these competencies underpin the mark schemes. Information on each of these three competencies is provided below.

Written and Verbal Communication
What does this term mean in the context of The Brilliant Club? Written and verbal communication relates to how pupils acquire and demonstrate knowledge, skills and ambition through written and spoken language.
Why is it important? Written and spoken communication is the medium through which most attainment is assessed. A child's ability to communicate at an early age is considered the most important predictor of school performance and future cognitive skills (National Literacy Trust, 2005; Rosetti, 1996). This implies that children who are unable to communicate effectively will go on to underperform academically. Children from under-represented backgrounds typically have poorer communication skills than their peers, with particular delays found in language development (Law et al, 2011). Therefore, a greater emphasis needs to be placed on developing communication skills from an early age (Lawton & Warren, 2015; Locke et al, 2002).
How can it be assessed? Our programmes assess written communication using pupils' final assignments. These are pieces of academic work based on cutting-edge research and completed after a series of university-style tutorials. Final assignments are marked at a key stage above pupils' current level of attainment, with marks being awarded for structure and clarity of communication. A pupil's performance on the final assignment is compared with their performance on the baseline test completed at the beginning of a programme. Going forward, the charity will also explore ways of assessing verbal communication. One way this can be done is by inviting pupils to subjectively rate their levels of confidence before and after taking part in the programme. This will enable pupils to self-report their levels of confidence in their verbal communication. These confidence ratings can then be further supplemented by feedback from their classroom teacher, as well as their tutor.
Subject Knowledge
What does this term mean in the context of The Brilliant Club? Subject knowledge relates to the academic strand of our programmes, in which pupils are taught new knowledge based on cutting-edge research.
Why is it important? Bloom (1956) argues that subject knowledge is a key building block needed for learners to be able to develop higher-order thinking skills, such as analysis and evaluation. Inter-dependence between subject knowledge and higher-order thinking has been highlighted in more recent theoretical models as well (e.g. Anderson & Krathwohl, 2001; Dwyer et al, 2014; Marzano, 2001). It has been argued that it is impossible to use higher-order

thinking skills without having the associated subject knowledge about which to think critically (Dwyer et al, 2014; Krathwohl, 2002). The idea that subject knowledge is key to learning is widely accepted amongst academics and educators, with this often being at the core of academic assessments (e.g. Momsen et al, 2010).

How can it be assessed? Our programmes assess subject knowledge using course-specific multiple-choice tests, as well as the final assignments referenced above. These two assessment methods allow for both open-ended and close-ended responses to be measured.

Critical Thinking

What does this term mean in the context of The Brilliant Club? Critical thinking is linked to a range of cognate skills, including: intelligence, problem-solving and higher-order thinking (Bangert-Drowns & Bankert, 1990). Definitions of critical thinking include: purposeful reflection and logical reasoning (e.g. Brookfield, 1987; Ennis, 1989; Paul, 1992); the ability to construct and evaluate arguments (Facione, 1986); and engaging in reflective scepticism (McPeck, 1981). Critical thinking has also been defined in relation to other skills, including meta-cognition (Flavell, 1979; Kuhn, 1999; Gelder, 2005).

A number of cognitive skills underpin critical thinking, including interpretation, analysis, evaluation, inference and explanation (Facione, 1990a; Facione, 2015; Giancarlo & Facione, 2001; Watson & Glaser, 1980). Critical thinking can be assessed at either a subject-specific or at a general level (i.e. content-independent). However, the literature shows that improvements in critical thinking are more likely to occur when activities focus on content related to a specific course (McMillan, 1987; Renaud & Murray, 2008; Terenzini et al, 1995).

As well as skills, critical thinking dispositions have also been identified. Critical thinking dispositions refer to personal attributes and behavioural tendencies linked to critical thinking, such as open-mindedness and inquisitiveness (Facione, 1990a; Facione, 2000; Facione, & Giancarlo, 1996; Facione et al, 1995). While there is some debate regarding the malleability of critical thinking dispositions, there is evidence to suggest that with appropriate instruction and teaching critical thinking skills can be developed (Abrami et al, 2008).

Why is it important? Critical thinking is widely recognised as a central aim of education, and one of the key skills needed for higher education and the workplace (American Association of Colleges and Universities, 2005; Ku. 2009; Lai, 2011; Pellegrino & Hilton, 2012). The ability to think critically is important within subject disciplines but also when thinking about challenges in daily life, including social, economic and political issues (Abrami et al, 2008). Despite its importance, developing critical thinking is challenging and schools tends lack explicit critical thinking instruction (Pithers & Sodden, 2000). Research has also indicated that a pupil's background is an important factor contributing to critical thinking, and that individuals from poor or less affluent backgrounds are less likely to increase their critical thinking whilst at university (Cheung et al, 2001).

How can it be assessed? Various assessments are available to assess university students' critical thinking both at a subject-specific and at a general level (Ku, 2009). Subject-specific critical thinking tests exist for certain subjects including biology, psychology and statistics. Several standardised measures also exist for general critical thinking. The response format of general critical thinking tests tends to be multiple-choice, as found in the Watson-Glaser Critical Thinking Appraisal (WGCTA; Watson & Glaser, 1980), California Critical Thinking Skills Test (CCTST; Facione, 1990b), and the Cornell Critical Thinking Test (CCTT; Ennis, Millman & Tomko, 1985). Some tests use an open-ended format which requires individuals to write an essay. An example of this is The Ennis–Weir Critical Thinking Essay Test, (Ennis &Weir, 1985). The standardised tests discussed above typically have been used for commercial purposes.

The Brilliant Club's programmes assess subject-specific critical thinking in a number of ways, particularly the final assignments that pupils complete. The assignments assess analysis, the construction of arguments and evaluation. As outlined above, critical thinking and meta-cognitive skills overlap, and critical thinking can also be assessed using meta-cognitive self-report inventories and assessing pupils' monitoring accuracy (Kuhn, 1999).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