

	<p>used are your own and not just those established by the organization.</p> <p>Structural conventions: essays in the sciences often include more data than other subjects, so make sure that data tables, diagrams and graphs can be clearly understood and are appropriately labelled, and that all data is clearly processed. Examples of calculations should include mathematical uncertainties on the measurements collected.</p>
B: Knowledge and understanding	<p>Knowledge and understanding must be demonstrated by exploring and discussing the underlying processes and theories, using clear and well-explained terminology. This is especially critical in essays based on secondary data. For example, when investigating the turnover rate of an enzyme, it is essential to discuss enzyme kinetics.</p>
C: Analysis and line of argument	<p>Analysis must follow standard processes, including qualitative and quantitative approaches and statistical methods where appropriate, and may include mathematical transformation. The analysis should be done in such a way as to address the research question directly.</p> <p>Analysis of secondary data must be your own.</p> <p>A clear line of argument should be maintained throughout and all elements of your sciences extended essay should be linked; only then is it effective in communicating your message. For example, if the topic is about the kinetics of photosynthesis, then discussion of the morphology of plant leaves is not relevant.</p> <p>If the research question is not fully answered, you should state unresolved issues, account for these and suggest improvements.</p>
D: Discussion and evaluation	<p>The discussion should be critical, have a scientific context and must always be linked to the research question. Ensure that discussions use the sources to support conclusions.</p> <p>The conclusion should not be a repetition of results but a supported, well-explained synthesis of them.</p> <p>The evaluation of your essay should indicate any unresolved issues, accounting for these and suggesting improvements, and should be linked to the findings and the research question.</p>
E: Reflection	<p>Refer to the “Generic guidance for the extended essay” and the “Reflection and the extended essay” sections of this guide.</p>

Mathematics

Note: Before reading the following guidance, read the “[Generic guidance for the extended essay](#)” section in this guide.

What is distinctive about an extended essay in mathematics?

An extended essay in mathematics should generally take one of the following approaches.

- Explore an issue in mathematics of interest to you that is outside of the syllabus. Sometimes in the course of your studies or in your wider reading, your curiosity might be aroused by a problem in mathematics or a different approach to mathematics that you might be interested to explore: see examples 1, 2 and 3 under “Example topics, research questions and approaches” below. These could be called **theoretical** essays.

- You might learn of how mathematics can be used to investigate an issue you are interested in. This issue could come from your career aspirations, a creativity, activity, service (CAS) project, an interest or hobby of yours, or from another subject. If the issue arises from another subject, you could consider the interdisciplinary pathway for your extended essay: see examples 4 and 5 under “Example topics, research questions and approaches” below. These could be called **practical** essays.
- You might have a passion for a sport or an interest from which you can get some data. Choose a mathematics extended essay and analyse the data, probably using your knowledge of statistics, to answer your research question. If the topic is something you love, you will especially enjoy writing your extended essay: see example 6 under “Example topics, research questions and approaches” below.

Note that your essay does not have to be entirely practical or theoretical. Many essays will be a mixture of both. In any case, note that it is mandatory to include secondary research, i.e. a review of the literature.

Remember that mathematics uses a lot of algebra, so the actual final word count for your extended essay is likely to fall short of 4,000 words.

Choosing a topic

The extended essay is your opportunity to explore an area of personal interest. If this interest is a branch of mathematics or if you plan to use mathematics to explore an interest, then your next task is to narrow this down to a topic. In more theoretical essays, the topic could clearly demonstrate the area of mathematics you will be exploring. In more practical essays, the topic could indicate how mathematics can be used to explore your area of interest. Once you choose your topic of interest, provided it is narrow and sufficiently focused, you should be able to come up with a provisional research question. As your research proceeds, you may decide that the exact wording of the research question needs to change a little to adapt to the direction your research is taking.

Be careful with research questions that compare two different approaches to a topic. It can sometimes be difficult to show a full understanding of the mathematics behind both. For instance, example 1 under “Examples of topics, research questions and approaches” below would be better than “Compare RSA with elliptic curves as a method of encryption”. You would need to explain carefully the mathematics behind both RSA and elliptic curves: this will not be fully achievable within 4,000 words. Avoid taking on too much and sacrificing showing a clear understanding of the mathematics in trying to fit it all in.

Example topics, research questions and approaches

Topic	Research question	Outline of approach
Mainly theoretical essays		
1. Cryptography	What is RSA (Rivest–Shamir–Adleman) encryption and how does it help make the internet secure?	Explain carefully how RSA works, making sure you show a full understanding of any mathematics used that is beyond the syllabus. Explain how this is used to make online transactions secure.
2. To infinity and beyond	How many infinities are there?	Explore countably infinite sets, explaining concepts clearly and proving your ideas. Progress to the uncountable continuum and discuss how this might be extended further.
3. Fractal dimension	What are fractals and what is fractal dimension? or Length of a coastline	Explain how fractals develop and explain their importance, perhaps exploring some limits problems such as finite area and infinite perimeter. From here, you could progress to the length of the

Topic	Research question	Outline of approach
		coastline of a favourite island or to the idea of fractal dimension.
Mainly practical essays		
4. The last rhinoceros	How long do the rhinos have left?	Explore both the population size and the habitat of the rhinoceros. Can you come up with a realistic model for the population size or the habitat area? According to the model, which will reach zero first, population or habitat?
5. Getting to school by public transport	What is the quickest and/or cheapest route from your home to school?	Consider the transport system in your area and compare different ways of getting to school. Estimate travel and walking times; consider an algorithm such as Dijkstra and decide on your preferred route.
6. Winning the English football Premier League	What is "home advantage", and are Premier League football champions equally successful away from home?	Use raw data from the English Premier League football results to examine the distribution of goals scored at home and away. Is there a significant home advantage? Are the champions able to overcome this in their away games?

Researching and writing the essay

Before you begin writing your essay, you will need to do some research. In more theoretical essays, this research will mainly involve reading around the subject. Try to choose a few resources that are most relevant; too many sources can be confusing. Depending on the mathematics you want to explore, the use of subheadings in your extended essay may be helpful.

In your introduction, explain your research question clearly and what you plan to do, in your own words. It is important that you show understanding of the mathematics you will be using and that you start from what is familiar to you in the syllabus. If you do not fully understand it, leave it out and amend your plan. When you write about the mathematics, all essential steps need to be shown and explained in your own words. Do not rely too heavily on your sources and do not copy information directly from them. It must be clear to the reader that you fully understand what you are doing. If there is a complicated theorem you want to use, and you feel the proof is too difficult, it is acceptable to quote the theorem without proving it. But it is essential that you explain what it is for and give an illustrative example to show your understanding.

In more practical essays, the emphasis may be on collecting appropriate data to begin with. When writing your essay, after explaining the background, show the data first (in an appendix if there is a large amount). For examples 4 and 6 above, you would need to start by graphing the data before deciding what to do with it. For this reason, it is better not to specify the mathematics or statistical methods you use in the research question because this may change once you examine your data. Your research then may involve learning (and explaining) some new mathematics to help you analyse the data. However, note that using mathematics from outside the syllabus is not essential. You may be able to answer your research question using the mathematics you have covered in your syllabus.

Do make sure you use raw data. It is difficult to do much with data that has already been processed, for example, batting averages in baseball.

Considering the assessment criteria

Make sure you use the extended essay assessment criteria to remind yourself of the expected elements of the extended essay. Each of the five criteria (A–E) is accompanied by a guiding question that should be applied to the context of mathematics. In this way, you can see how the assessment criteria relate to your own essay. It is important that you also refer to the “[Generic guidance for the extended essay](#)” section in this guide for a broader spectrum of advice on using the assessment criteria to inform your writing.

A: Framework for the essay	Clearly state your research question and ensure your essay remains focused on it throughout. Make sure your mathematics is written well by using an equation editor. This will help you avoid poor mathematical presentation, such as not using a new line for each step in your algebra, or using inappropriate symbols like * for multiplication and ^ for powers.
B: Knowledge and understanding	Showing your knowledge and clear understanding of the mathematics you use is arguably the most important criterion in a mathematics essay. If you have not shown that you really understand the mathematics, this will impact other criteria. Do not be overly ambitious—an extended essay is not a research paper revealing that you have discovered something profound and new. Understand and explain something that is new to you (in more theoretical essays) or apply some mathematics that you understand well in a situation that is new (in more practical essays).
C: Analysis and line of argument	Avoid the temptation to extend your analysis beyond the realm of your research question—this is likely to lessen the impact of your essay. In more practical essays, it is better that the techniques you use to analyse your data are decided based on looking at that data, rather than being predetermined. In more theoretical essays, make sure that the mathematical theory described, and the illustrative examples used, remain focused on the research question. This will result in a consistent line of argument.
D: Discussion and evaluation	Clearly discuss the relevance of your findings throughout the essay, not just in the conclusion. Consider the strengths of what you have found and describe any limitations. In more practical essays, discuss the findings from your data and ensure this informs how you proceed through the essay. In more theoretical essays, explain how the theory you are developing is relevant to your research question. In both cases, ensure that the conclusions you reach are relevant to your research question and are supported by findings in your essay.
E: Reflection	Refer to the “ Generic guidance for the extended essay ” and the “ Reflection and the extended essay ” sections of this guide.

Arts

Note: Before reading the following guidance, read the “[Generic guidance for the extended essay](#)” section in this guide.

What is distinctive about an extended essay in the arts?

An extended essay in the arts allows you to explore a topic of particular interest to you in dance, film, music, theatre or visual arts. It can include a wide range of dynamic creative practices through which human beings convey ideas, communicate experiences, values and impressions, and develop identity. Any essay in this area should integrate the analysis of primary sources—such as artworks, films, live performances, music concerts, play texts, screenplays, scripts and scores—with disciplined research informed by scholarly