Instructions for candidates

This assessment applies to the project for Advanced Higher Physics.

This project is worth 30 marks. This contributes 25% to the overall marks for the course assessment.

It assesses the following skills, knowledge and understanding:

- extending and applying knowledge of physics to new situations, interpreting and analysing information to solve more complex problems
- planning and designing physics experiments/investigations, using reference material, to test a hypothesis or to illustrate particular effects
- recording systematic, detailed observations and collecting data
- selecting information from a variety of sources
- presenting detailed information appropriately in a variety of forms
- processing and analysing physics data (using calculations, significant figures and units, where appropriate)
- making reasoned predictions from a range of evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- critically evaluating experimental procedures by identifying sources of uncertainty, suggesting and implementing improvements
- drawing on knowledge and understanding of physics to make accurate statements, describe complex information, provide detailed explanations, and integrate knowledge
- communicating physics findings/information fully and effectively
- analysing and evaluating scientific publications and media reports

This project has two stages.

- research
- report

Your teacher or lecturer will let you know if there are any specific conditions for doing this assessment.

In this project, you have to investigate a topic in physics by doing research. You will work individually to gather data/information from your own experiments and from internet/literature research. This may involve you carrying out a significant part of the work without supervision.

Your research involves planning experiments and gathering data. An Advanced Higher Physics project typically consists of **three or four** related experiments. You should plan to spend approximately 10 to 15 hours doing experimental work.

You will gather information from internet/literature sources to support your understanding of the underlying physics. From the start of your project, and throughout, you should maintain a record of your work in a daybook.

You then produce a report on your project.

Your teacher or lecturer will not mark your report at any point. It is sent to SQA for marking.

Research stage

At the start of your project, it is advisable to set up a timescale with start dates and deadlines for each stage of your project, for example:

Stage	Start date	Tasks	Deadline dates
Research — planning		Read the 'Instructions for candidates'.	
		Discuss your choice of topic with your teacher or lecturer.	
		Decide on the aim of your project. Discuss the suitability of your aim with your teacher or lecturer.	
		Research the physics underlying your chosen topic.	
		Research possible experiments and show your teacher or lecturer a detailed plan of the experiments you intend to carry out.	
Research — experimental		Check that the apparatus will be available for you whenever you need it.	
		Complete the experimental work. Allow time to carry out repeated measurements. Allow 10 to 15 hours for your experimental work.	
		Analyse your experimental results, including uncertainties, by drawing graphs and performing calculations.	
		Consider your conclusion(s).	
		Evaluate your experiments.	
Report		Complete a draft of your report.	
		Finalise your report.	

You should include a copy of this table in your daybook.

Choosing your topic

- You need to choose a topic in physics to investigate.
- You must agree your topic with your teacher or lecturer.

Keeping a daybook

Your daybook should contain a complete record of the work you carry out during your project.

Your daybook should include:

- the date of each entry in the daybook
- a description of your experimental procedures
- all measurements, which should be tabulated
- any observations
- analysis of experimental data, including uncertainties (Plotting graphs while data is being collected allows rogue points to be identified. Ongoing analysis of your experimental data allows you to plan what you will do next.)
- notes on any discussions with your teacher or lecturer and any advice given
- information collected from internet/literature sources, including references

It is important to write your entries into your daybook so that it is easy to follow and understand when you produce your report.

It is important that you ask your teacher or lecturer to check your daybook regularly and take their advice.

Deciding your aim

- Once you have chosen your topic, you need to decide what the aim of your project is.
- Remember that you need to plan, carry out and collect data from experiments that relate to your aim.
- Your teacher or lecturer will give you advice on the suitability of your aim.

Experimental research

- When planning your experiments, remember that they must allow you to take measurements and plot scatter graphs.
- When carrying out your experiments, you must work on your own.
- Make sure you take a sufficient number of measurements over a wide enough range to meet the aim of your project.
- You must repeat measurements.
- You must estimate both the scale reading uncertainty in all the measurements you make, and record the calibration uncertainty in the instruments you use.

Internet/literature research

- In your report, you will need to show that you understand the physics underlying your project. You can use information from websites, books and/or journals to help you write your description of the underlying physics. In your report, you will need to show your understanding by writing this account using your own words.
- It is important that you record where you get your information. In your report, you will need to cite and reference at least three of your sources using either Vancouver or Harvard referencing systems.

Report stage

Producing the report

The report must be all your own work.

Resources

The information you recorded in your daybook should form the basis of your report.

You can access any resources you need to write your report.

Guidance on producing your report

The following table shows the marks allocated to each section in your report.

Sections	Mark allocation
Abstract	1
Underlying physics	4
Procedures	7
Results (including uncertainties)	8
Discussion (conclusion(s) and evaluation)	8
Presentation	2
Total	**30**

Using headings may help to make your report clear.

Title page

This page must have a title that clearly indicates the subject matter of the project. You might start out with a working title and then consider revising the wording of the title as the project nears completion. The title page must also have your name and candidate number and the name and number of the presenting centre.

Abstract

In your abstract, you must state the aim and overall findings/conclusion(s) of the project. The abstract must be brief and should be immediately before the contents page. Although it appears early in the report, as the abstract summarises the project, it may be one of the

last things you write. Your overall findings must be consistent with your conclusion(s) and must relate to the aim.

Contents page

This page must list the sections within the report and their corresponding page numbers, for cross-referencing purposes. It is essential that you number all pages in the report.

Underlying physics

You must include a description of the underlying physics that is relevant to the project. This account must show your understanding of the physics underlying your chosen topic. You should derive any relationships you use and define abbreviations and symbols.

You might draw on a variety of sources of information when you are researching your chosen topic. In your account of the underlying physics, use terms accurately and explain ideas clearly. You should also include diagrams, as appropriate.

Your report must reference at least three sources of information you used. You must cite them in the text and list them at the end of the report. The information from the sources could either have supported your understanding of the physics or helped you to plan your experiments.

Copying directly from the internet, books or journals may suggest to the marker that you have not understood the physics involved, and may be considered as plagiarism. It is always better to put things into your own words.

Procedures

This section must contain an account of the procedures you carried out in your project. The procedures must be clearly described in sufficient detail to allow the project to be replicated. Include details of all the apparatus, methods and materials used to obtain your data.

In broad terms, the procedures should allow the aim to be achieved.

The experimental procedures that you use in your project must be at an appropriate level of demand for Advanced Higher Physics.

You must include labelled diagrams and/or descriptions of the apparatus that you used for experimental work. Clear, uncluttered photographs of assembled apparatus, with appropriate labelling, are acceptable. You should include circuit diagrams, including the value of components, where appropriate. Simple lists of apparatus, on their own, are not sufficient.

You must also include clear descriptions of how you used the apparatus to obtain your experimental results. You must include sufficient detail to allow your project to be replicated by another person. Include the range and interval of measurements and number of repetitions, where appropriate.

You must write the description in the past tense and use the impersonal passive voice.

Bulleted or numbered points are only acceptable if the statements are sentences and are meaningful and coherent. They must make sense if the numbers or bullet points were to be removed. Your description must not be a list of instructions.

Results (including uncertainties)

The results must be relevant to the aim of your project.

In the results section, you must provide all raw data as well as processed or derived data. Raw data are the measurements you actually record in each experiment.

You must include all the measurements taken (not just the mean values) and show by sample calculation how they were processed to produce a final result.

You should show the treatment of uncertainties in this section. You must quantify all (calibration, scale reading and random) uncertainties in measurements used in your analysis. You must combine these to determine the uncertainty in each measured value, and combine the uncertainties in each measured value to determine the uncertainty in the final result. This may include the determination of the uncertainty in the gradient or intercept of a line of best fit.

You must present measurements and processed data clearly, with appropriate use of tables, scatter graphs and calculations. Tables must have appropriate headings and units must be specified. Graphs must have appropriate axis labels with units specified.

For your graphs, you must include tables of measurements and any derived values that you used to plot your data points. A graph on its own is not sufficient — you must also present the data from which it has been derived.

When drawing a graph, you must ensure that:

- it is large enough to allow the accuracy of plotting to be checked
- scales are chosen so that the plotted points are widely spread
- each axis is labelled with the name of the quantity and the correct unit
- data points are plotted accurately
- a line of best-fit is drawn, where appropriate

When you use graphing software to present graphs, it is important to adapt the axes to suit the data range so that you can present the results in the most appropriate way. You must include major and minor gridlines and use symbols for data points that are clear, but not excessively large.

You must clearly structure any calculations. When you repeat the same type of calculation for different raw data, you only need to set out one sample calculation in detail, but you must always give all the raw data.

You must take care with significant figures in presenting and processing data. In calculations, for example, it is appropriate that intermediate results carry a number of

extra digits beyond the last significant one, but you must quote the raw data and final results to an appropriate number of significant figures.

The number of significant figures in the final calculated result depends on the apparatus used and the precision of the measurements taken. This is usually the same as the lowest number of significant figures in any measurement used to determine the final result. The number of significant figures is not the same as the number of figures after the decimal point. For example, the values 20·6 and $1{\cdot}40 \times 10^{-5}$ each have three significant figures. However, 0·06 and 1×10^{-5} have only one significant figure.

Discussion (conclusion(s) and evaluation)

In your discussion section, you must include a clear statement of the overall conclusion(s), an evaluation of your procedures and a critical evaluation of the project as a whole.

The discussion section is an important part of the report, and in it you must discuss your findings in a critical and scientific manner. It gives you an opportunity to demonstrate the depth of your understanding of the experimental physics in your project.

You should give conclusions and evaluations for each individual experiment.

You should demonstrate understanding of the physics involved when you are discussing the results of the project as a whole.

Your overall conclusion(s) must relate to the aim of the project and they must be valid for the results obtained.

In the evaluation of your procedures, you should comment on the accuracy and precision of your measurements, and the source(s) of dominant uncertainties. You should make suggestions for improvement, including justifications.

You could consider:

- the accuracy and precision of experimental measurements
- the adequacy of the number of repeated measurements
- the adequacy of the range over which variables are altered
- the adequacy of control of variables
- limitations of equipment
- the reliability of methods
- sources of uncertainty

In the critical evaluation of the project as a whole, it is important that you emphasise positive aspects relating to the procedures, as well as commenting on:

- selection of procedures
- problems encountered during planning
- modifications to planned procedures
- interpretation and significance of findings

- suggestions for further improvements to procedures
- suggestions for further work

Presentation

You should use a structure for your report that is clear and flows logically. Your report must have a title page with an informative title. It must have a contents page with section headings and their corresponding page numbers. You must number all the pages in your report.

You must cite and reference at least three different sources of information that you have used.

Different pages from the same book count as **one** reference only. Similarly, if you refer to different areas of the same website, this too counts as **one** reference only.

A reference is any piece of material that a writer refers to in the text. You must list each reference at the end of your report to provide information about the source of the material referred to. This allows the reader of your report to consult the original work if necessary and is also an acknowledgement of the work of other authors.

Copying directly from the internet, books or journals without acknowledgement is plagiarism. It is also plagiarism to present others' ideas as your own. The purpose of referencing is to show clearly which ideas or words are not your own, to provide enough information for someone else to find the source of those ideas or words, and to present that information consistently. You **must** use either Vancouver or Harvard referencing systems. Guidance on citing and referencing textbooks, websites and journals is given below:

Textbooks

1 Vancouver

You must cite books in the body of the text by a number, for example [1], (1) or [1].

You may include the page numbers with the citation, for example [1, p.22] or with the reference, for example (p.38–42). This is useful when you are citing different pages in the same book where it has been used more than once. Citations can also be listed using the author's name, but should still have the number, for example Tyler[1]. If you are citing multiple sources in one section of the report, you can list all of these in the same place, for example (1, 3, 4). When there are a number of authors, you should include at least one of the authors and list the others as 'et al', but you should still include the citation number, for example Sears et al[2].

Include as many of the following details as possible in your references:

- author(s) or editor(s): author's forename and/or initials and surname
- title of book
- edition number (if other than first edition)
- place (city) of publication

- publisher's name
- year of publication
- page numbers

For example:

1 J.O. Bennett, M.O. Donahue, M. Schneider, M. Voit *The Cosmic Perspective*. 8th Edition. New Jersey: Pearson Education; 2016. p. 47-52

2 Harvard
You must cite books in the body of the text in parentheses with the author's surname and the year of publication, for example (Tyler, 1977).

You may include the page numbers with the citation, for example (Tyler, 1977 pp. 45–48). Note: if there are three or fewer authors, you should cite them all, for example (Horowitz & Hill, 1989). When there are four or more authors, cite the first author and follow this with 'et al', for example (Bennett et al, 2014).

Include as many of the following details as possible in your references:

- author(s) or editor(s)
- title of book
- edition number (if other than first edition)
- place (city) of publication
- publisher's name
- year of publication
- page numbers

For example:
Tyler, F *A Laboratory Manual of Physics in S.I. Units*. 5th Edition. London: Edward Arnold; 1977. pp 45-48

Websites

1 Vancouver
You must cite websites in the body of the text by a number, for example [1], (1) or [1].

Include as many of the following details as possible in your references:

- author/editor (use the corporate author if no individual author or editor is named)
- title (this should be in italics)
- the URL
- the date of access (this should be enclosed in square brackets)

For example:

1 Dumé, B. *Could sound move at the speed of light?*
Available from: *http://physicsworld.com/cws/article/news/2005/nov/01/could-sound-move-at-the-speed-of-light* [accessed 01/05/19].

2 Harvard
You must cite websites in the body of the text in parentheses with the author's surname and the year of publication, for example (Dunning, 2017). If no date is given, use 'n.d.', for example (author, n.d.).

Include as many of the following details as possible in your references:

- author (year)
- article title (this should be in italics)
- website title
- URL
- the date of access

For example:
Dunning, H. (2017). *Theory that challenges Einstein's physics could soon be put to the test*. [online] www.imperial.ac.uk. Available at: http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_24-11-2016-10-12-58 [Accessed 1 May 2019].

When no clear author or organisation can be attributed, cite the URL as far as the first '/' in the text, but do not include 'http://www.', for example (cimt.org.uk) and list the full URL in the reference list with the date accessed, for example:
https://www.cimt.org.uk/projects/mepres/alevel/mechanics_ch8.pdf [Accessed: May 2019]

Journals: print

1 Vancouver
You must cite journals in the body of the text by a number, for example [1], (1) or [1].

Include as many of the following details as possible in your references:

- author(s)
- title of journal article
- title of journal (this should be in italics)
- year of publication
- volume number
- issue number (this should be enclosed in brackets)
- page numbers of the article

For example:
Davies R., Bacon R., de Zeeuw T. Sauron. *Frontiers UK particle physics, astronomy and space science*. 2004:18 (winter):14–15.

2 Harvard
You must cite journals in the body of the text in parentheses with the author's surname and the year of publication, for example (Ball, 2012).

You may include page numbers, for example (Ball, 2012 pp. 46-50). Note: if there are three or fewer authors, you should cite them all, for example (Davies, Bacon & de Zeeuw, 2004). When there are four or more authors, cite the first author and follow this with 'et al', for example (Bennett et al, 2014).

Include as many of the following details as possible in your references:

- author
- year of publication (this should be enclosed in brackets)
- title of journal article
- title of journal (this should be in italics)
- volume number
- issue number
- page numbers of the article (do not use 'p.' before the page numbers)

For example:
Edgecock, R. (2004) Cooling muons with MICE. *Frontiers UK particle physics, astronomy and space science*. 2004:18 (winter):24–25.

A number of websites include detailed guides for referencing, for example:

Vancouver: https://www.imperial.ac.uk/media/imperial-college/administration-and-support-services/library/public/vancouver.pdf

Harvard: https://www.imperial.ac.uk/media/imperial-college/administration-and-support-services/library/public/harvard.pdf

Online referencing tools can automatically format the citation and reference for a chosen style. You should consider using one of these.

Summary

You can use this table to check you have covered all the sections in the report.

Section	Expected response	Mark allocation
Abstract	A brief abstract (summary) stating the overall aim and findings/conclusion(s) of the project.	1
Underlying physics	A description of the underlying physics that: ♦ is relevant to the project ♦ demonstrates an understanding of the physics theory underpinning the project ♦ is of an appropriate level and commensurate with the demands of Advanced Higher Physics	4
Procedures	Labelled diagrams and/or descriptions of apparatus, as appropriate.	2
	Clear descriptions of how the apparatus was used to obtain experimental readings.	2
	Procedures are at an appropriate level of complexity and demand. Factors to be considered include: ♦ range of procedures ♦ control of variables ♦ accuracy and precision ♦ originality of approach and/or experimental techniques ♦ degree of sophistication of experimental design and/or equipment	3
Results (including uncertainties)	Data is sufficient and relevant to the aim of the project.	1
	Appropriate analysis of data, for example, quality of graphs, lines of best fit, calculations.	4
	Uncertainties in individual readings and final results.	3
Discussion (conclusion(s) and evaluation)	Valid conclusion(s) that relate to the aim of the project.	1
	Evaluations of experimental procedures to include, as appropriate, comment on: ♦ accuracy and precision of experimental measurements ♦ adequacy of repeated readings ♦ adequacy of range over which variables are altered ♦ adequacy of control of variables ♦ limitations of equipment ♦ reliability of methods ♦ sources of uncertainties	3

Section	Expected response	Mark allocation
	Coherent discussion of overall conclusion(s) and critical evaluation of the project as a whole, to include, as appropriate, comment on: ♦ selection of procedures ♦ problems encountered during planning ♦ modifications to planned procedures ♦ interpretation and significance of findings ♦ suggestions for further improvements to procedures ♦ suggestions for further work	3
	A report which indicates a quality project.	1
Presentation	Appropriate structure, including informative title, contents page and page numbers.	1
	References cited in the text and listed at an appropriate point in the report. Citing and listing using either Vancouver or Harvard referencing system.	1
Total		**30**