External Assessment Report 2015

Subject(s)	Physics
Level(s)	AH - Traditional

This report provides information on the performance of candidates which it is hoped will be useful to teachers/lecturers in their preparation of candidates for future examinations. It is intended to be constructive and informative and to promote better understanding. It would be helpful to read this report in conjunction with the published question papers and marking instructions for the examination.

Comments on candidate performance

General comments

Number of Candidates

- 2007 1370
- 2008 1396
- 2009 1530
- 2010 1707
- 2011 1746
- 2012 1905
- 2013 1854 (plus 62 early adopters for revised) Total = 1916
- 2014 1804 (plus 113 Revised) Total = 1917
- **2015 1840 (plus 178 Revised) Total = 2018**

The first time entries have exceeded 2000.

Examination

A fair paper with the vast majority of candidates making a good attempt at all questions. Candidates did not appear to be short of time.

Investigation

The mean investigation mark was unchanged at 14.2 indicating a similar cohort to 2014.

Some candidates still submit very poor attempts which tend to lower the mean value. This is disappointing since marks can easily be picked up by following the Candidate's Guide, which can be downloaded from the SQA website.

Mean Mark per category

Category	**Max Mark**	**Mean Score 2011**	**Mean Score 2012**	**Mean Score 2013**	**Mean Score 2014**	**Mean Score 2015**
Introduction: Summary	1	0.8	0.7	0.73	0.69	0.67
*Underlying Physics	3	1.2	1.2	1.25	1.42	1.35
Procedure: Diagrams	2	1.1	1.1	1.11	1.11	1.16
Description	2	1.2	1.1	1.17	1.18	1.24
*Level of Demand	2	1.0	1.0	1.01	1.09	1.10
Results: Data	1	1.0	1.0	0.94	0.96	0.99

*Uncertainties	3	1.3	1.3	1.30	1.47	1.37
Analysis	2	1.0	1.0	1.04	1.07	1.04
Discussion :Conclusion	1	0.8	0.8	0.83	0.79	0.82
*Evaluation procedures	3	1.2	1.2	1.19	1.25	1.29
*Investigation as a whole	2	0.6	0.7	0.66	0.65	0.64
Presentation: Title	1	1.0	1.0	0.97	0.96	0.96
Clarity	1	0.9	0.8	0.85	0.87	0.86.
References	1	0.6	0.6	0.70	0.64	0.65
Mean Mark		**13.7**	**13.7**	**13.75**	**14.15**	**14.16**

You should refer to the comments below in conjunction with the examination paper and the Marking Instructions that can be downloaded from: http://www.sqa.org.uk/sqa/40814.html

Areas in which candidates performed well

Examination

1: Candidates are confident handling the relativistic mass equation.

2: Rotational dynamics — candidates demonstrated a sound knowledge of this topic.

6(b): Candidates tackled this question well, with many able to calculate the vertical deflection of the alpha particle and explain how an increase in plate separation would affect the magnitude of the vertical deflection.

7(a)(i): Candidates were able to explain about a central force producing circular motion.

7(a)(ii): Derivation of formula – there was a good improvement from candidates in showing all the steps in a ‘show’ question.

8(a)(ii): Most candidates now recognise that a **negative** emf must be substituted in the formula.

9(a): Most candidates were able to calculate the magnitude of magnetic induction at a point.

10(a)(i): Most candidates gave the correct description of how the frequency changes for both moving towards and away from the policeman.

10(b): Many candidates were able to explain the approximation of the expression and then apply the relationship in a calculation.

11(a)(ii): Candidates demonstrated good application of formula, after calculating the fringe separation.

11(a)(iii): Most candidates are confident tackling uncertainty calculations.

Investigation

Results

Uncertainties: Improvement in use of calibration, reading, random uncertainties and their combination.

Analysis: Spreadsheet use increasing, good use of LINEST function to calculate the uncertainty in the gradient of a straight line. It would be beneficial if candidates explained or highlighted the LINEST data.

Discussion

Conclusion: most gained a mark for this with clear links to the aim of the investigation.

Presentation: the majority of candidates gained two marks for the first two areas, although some made it difficult for the marker by grouping the diagrams, description and results. This caused a lack of 'flow' for the reader.

- Contents and page numbers – excellent
- Clear and concise – almost all candidates produced clear and concise reports.
- References – most were at the end **and** also cited in the text — mainly in 'Underlying Physics'.

Areas which candidates found demanding

Examination

3(a): Many candidates knew how to equate gravitational force and centripetal force, but did not explicitly state that $\omega = 2\pi/T$ outwith the derivation.

5(b): There was a surprisingly poor response in the comparison of the number of up and down quarks in the daughter product compared to the Bismuth.

6(a)(i): The basic definition of a *uniform electric field* was not fully understood ie force per unit charge is constant between the plates.

6(a)(ii): Too many candidates did not use the gradient of the graph to find E and instead chose data points that did not lie on the line of best fit.

6(a)(iv): There was a very poor response to this question — stating that there is a systematic uncertainty, calibration uncertainty, either on their own, is not sufficient. Candidates must be more specific in their responses.

7(b): Many candidates realised how the circular component arose but did not also state that the horizontal component is a constant speed.

7(c): Those who had the right idea for this question generally scored 2.5 / 3, as they failed to half the period of the oscillation. A fair proportion of candidates did not know how to approach this question, even though it was simply an application of the speed, distance, time equation.

8(a)(i): There was a very poor response to this question. Many candidates did not know basic electrical symbols and where components should be placed in a circuit.

D.C. supplies were often used instead of variable frequency ac (signal generator)

Ammeters should not be connected in parallel and voltmeters / oscilloscopes in series!

8(a)(ii): The question required candidates to determine the relationship between supply frequency and current for an inductor. At AH level, it is not appropriate to answer simply 'as the frequency goes up, the current goes down'.

10(a)(iii): Candidate responses to parts A and B indicated a true lack of real understanding of the situation. The correct answer really highlights decreas**ing** frequencies.

11(a)(i): Disappointingly, many candidates did not fully understand that the double slits produce two coherent sources.

Investigation

Introduction

Underlying Physics: again very few candidates scored full marks — derivation of formulae was often not given. No cross-referencing linking to references at the back of the report. Symbols were often not defined.

There were too many scanned/copied explanations showing little understanding, some of which were referred for plagiarism.

Procedures

Diagrams: the image quality of photographs was often poor — perhaps because they were taken with a mobile phone. Care should be taken to label photographs and include normal diagrams for clarity. Several diagrams were still disappointing this year — lacking clarity and labelling. Circuit diagrams were often not included. Some candidates used snapshots, from a smartboard, of hand-drawn diagrams / theory. This is not advisable since the final product was very poor quality. In some cases, diagrams of theoretical apparatus were scanned, these often showed little resemblance to the apparatus that was actually used.

Descriptions: these were often not clear and to the point. A marker should be able to replicate the experiment **exactly** by following the description. The range of the variables was often omitted. No mention of how each quantity was measured and what equipment was used.

Too often only three repeated measurements were taken when there should really be a minimum of five.

Level of demand: some candidates had attempted just two experiments plus another that was only at Higher standard.

Uncertainties: Significant figures are still a problem. The absolute uncertainty in the final answer should be given to one significant figure.

Inappropriate averaging is still being used, sometimes to obtain a final mean figure, but also in intermediate steps.

One sample showing the calculation of uncertainties for a set of results is sufficient. There is no need to type out all of the uncertainty calculations for a set of results, it is sufficient to say that other similar calculations were carried out in the same manner. However, there should be a sample uncertainties calculation for each set of results in a report.

Analysis: there has been an increase in the use of spreadsheet packages to produce graphs. Although improving, there are still some issues with size, zero not shown, scaling, grid lines too large or missing and units missing or incorrect.

Graphs should not be forced through the origin and trendlines should be checked. The use of LINEST will see a drop in time spent on estimating the uncertainty in a gradient. Some candidates using LINEST do not seem to know the significance of its use. They will also go on to calculate the uncertainty using the parallelogram method.

Discussion (Quality areas)

Evaluation of experimental procedures: there was a lack of reference to and discussion of uncertainties quoted in the experiment.

Comments on the greatest uncertainties and how to minimise these were often missing. Candidates often mistakenly looked for improvements in experimental technique when the uncertainties in readings were small. A better approach would be to make a statement to discuss whether suggested improvements would make any difference. Candidates should have a feel for the purpose behind estimation of uncertainties. Too often it is seen as something that has to be worked through with little understanding of the significance of the uncertainties on the final results.

Evaluation of discussion as a whole: students still find this difficult. It could cover further work, frustrations, physics points, modifications, lost time, etc. There is still little evidence of reflection on procedures and findings.

Advice to centres for preparation of future candidates

Examination

Mark allocation

In the new Advanced Higher there are no ½ marks awarded, so:

- **4 or 5 marks** will generally involve more than one step or several points of coverage.
- **3 marks** will involve just one use of an equation or a number of descriptive points.

Use of data sheet

- Clearly show the substitution of a value from the data sheet, eg do not leave μ_o in an equation. Show the substitution $4\pi \times 10^{-7}$ in your equation.
- Rounding — do not round the given data sheet values, eg mass of a proton = 1.673×10^{-27} kg **NOT** 1.67×10^{-27} kg.
- Use the symbols given in the data sheet.

‘Show’ questions

- Generally **all steps** for these must be given, even although they might seem obvious. Do not assume that substitutions are obvious to the marker.
- All equations used must be stated separately and then clearly substituted if required. Many candidates will look at the end product and somehow end up with the required answer. The marker has to ensure that the path to the solution is clear. It is good

practice to state why certain equations are used, explaining the Physics behind them, eg derivation of escape velocity: $E_k + E_p = 0$ as a starting point.

Calculus — equations of motion

- $s = f(t)$
  Be clear that differentiating, with respect to time, once gives the velocity, differentiating twice gives the acceleration.
- $a = f(t)$
  Integrating once gives the velocity, integrating twice gives the displacement. Remember to take into account the constant of integration each time by considering the limits.

Definitions

Know and understand definitions given in the course. Definitions often come from the interpretation of an equation.

Diagrams

Use a ruler and use appropriate labels. Angles will be important in certain diagrams. On no account should ray diagrams be drawn freehand.

Circuit diagrams

Candidates could be asked to draw an appropriate circuit diagram or experimental set up.

The symbols for electronic components / apparatus should be committed to memory, ensuring that they are connected correctly for a required circuit / experiment.

Circuits drawn should allow measurement of all relevant quantities.

Graphs

- Read the question and ensure you know what is being asked. Label graph axes correctly (quantities and units) and do not forget to label the origin.
- Rearranging equations in the form of $y = mx + c$ so a suitable graph can be plotted to attain the gradient is an essential mathematical skill in AH physics.
- Sketch graphs — take care not to go over axes by accident. Candidates must understand that to ‘sketch’ a graph does not mean that the graph can be untidy or inaccurate. The instruction to ‘sketch’ a graph only means that **it does not have to be drawn to scale**. Care should still be taken to present these sketches as neatly as possible. For example, a ruler should be used to draw the axes and any straight sections of the graph line. The origin and axes on sketch graphs must be labelled and any important values carefully shown. It is useful to link these important values to the relevant parts of the graph line using dotted reference lines. It is wise to use a pencil when attempting to draw the graph line – any wrong line(s) can then be erased to leave a neat, clear, single line as the final answer.

Explain/describe questions

- These tend to be done poorly. Ensure you have covered all points and have read over your response again to check there are no mistakes. Try to be clear and to the point.

Uncertainties

Ensure you are comfortable with those listed below:

- Systematic, calibration, scale reading (analogue and digital) and random uncertainties.
- Percentage / Fractional uncertainties
- Combinations — Pythagorean relationship
- Absolute uncertainty in final answer (give to one significant figure).

If a systematic or calibration uncertainty is identified, the source of this uncertainty should be considered / discussed.

Uncertainties booklet is available at:
http://www.educationscotland.gov.uk/images/uncertainties_tcm4-121145.pdf

Experiment descriptions

Procedures describing unfamiliar experiments can still be attempted using basic rules of experimental technique, eg Identifying and stating how the variables are measured. There should be at least 5 data points with adequate repetition of each one.

- Relationships between the variables can be verified by plotting the appropriate graph.
- Candidates need to be able to correctly draw a circuit diagram using the appropriate symbols.

Unfamiliar questions

- Candidates might be given a relationship that they have not seen before. They should use their problem solving skills to attempt this type of question.

Incorrect units

- Marks were regularly dropped this year for incorrect units for gravitational potential, torque, moment of inertia, angular acceleration, linear acceleration and angular momentum.
- Units should be checked, if there is time, at the end of the exam.

Prefixes

- Candidates will lose marks for incorrect conversions of units. It is also better not to make a final step of say, converting an answer from m to nm, unless of course this is a requirement. Candidates will lose marks for an incorrect final answer.

Open-ended questions

- Candidates improve in performance with practice. It is very easy to spend too much time on these (worth 3 marks). Examiners are not looking for an essay.

Investigation

Each candidate should be given a copy of the Guidance to Candidates documents. Too many candidates fail to gain what should be ‘easy marks’ due to not having followed the advice.

- Some centres had duplicate investigations (results different) despite having a small number of candidates. It should be possible, where presentation numbers are small, for candidates to investigate different topics for their Project. This then avoids the issue of candidates having their work referred for suspected collusion, by ensuring that it is the candidate's individual work.
- It is important not to just hand out old investigations for viewing or triggering ideas, without ensuring their collection afterwards. It is better to use brief accounts of possible investigations so the students can research / plan these using appropriate references.
- The Project should comprise **three to four** related experiments — only in exceptional circumstances will one or two be sufficient to cover the recommended time of 10 – 15 hours experimental work.
- Investigations which duplicate procedures have tended to score low marks eg finding Young's modulus for five different materials using the same approach. It is better to find Young's Modulus for two different materials using three different methods.

Use of university facilities

It is pleasing to see schools using university support where possible. This not only gives the students experience of working in another environment, but also creates an opportunity for the universities to demonstrate the facilities available.

However, it must be said that if using these facilities for a Project, this should not be seen as quick fix so that the Project can be completed with one or two afternoons' lab work. Some have been well beyond the ability of the candidates and their reports demonstrated a lack of understanding. Quite often candidates were just following instructions from worksheets prepared by the university.

The high scoring 'university investigations' have clearly well planned and had either introductory experiments done in school or a more specialised experiment attempted at university to round off the investigation.

There was some evidence of universities treating the students' visits as a lab afternoon with technicians on hand to aid the students. Some experiments had tenuous links which highlighted poor planning.

Some schools are sending out pupils to universities and the pupils are attempting identical investigations. This is not recommended and these cases may be considered under suspected malpractice. Centres are reminded that the Project must be the work of the individual candidate.

AH Physics Project advice

In the CfE course, the investigation will now be called the project with a total of 30 marks.

The basic requirements will be the same as the investigation with the new allocation of marks shown below.

Every year candidates throw away easy marks by being careless in their report. The advice below can be used as a checklist to ensure maximum marks in the investigation.

Introduction (5 marks)

Abstract (1 mark)

The **aim(s)** and **findings** should be clearly set out so that someone reading the report clearly sees what lies ahead.

The experiments attempted should be clearly listed and the numerical results, including uncertainties given where appropriate.

Introduction (4 marks)

Here the candidate must demonstrate a good understanding of the theory. The theory must be relevant to the experiments that follow. All terms used should be clearly defined. Derivations should be shown and, if information is drawn from sources, they should be **cross-referenced**, linking to the reference list at the back. Equations should not be plucked out of thin air. Care should be taken not to cut and paste from referenced sources. It is also better to cover the theory for all experiments in this section. This area gives the markers an opportunity to reward quality.

Procedures (7 marks)

It is surprising how many candidates drop careless marks in the next two sections. With a bit of care, all should attain 4 marks for the diagram and apparatus use. Anyone reading the next two sections should be able to repeat the experiments with the detail given. References should be given for any specialised equipment.

Diagrams/descriptions of apparatus (2 marks)

There is an increase in the number of digital photographs, but unfortunately, in many cases they add nothing to the description of the experiment. **Do not include a photograph if it is not good quality**.

The background should be uncluttered. It might be an idea to illuminate the apparatus to aid clarity. A satisfactory photograph showing clear detail **should be labelled**.

Labelled circuit diagrams should be also be drawn where appropriate.

A labelled schematic diagram will also help clarify the set up.

Description of how apparatus was used (2 marks)

A clear account of the procedures should be given. Many candidates omitted the range of readings used, the number of repetitions made and the apparatus used to take measurements.

Someone reading the description should be able to replicate the experiment **exactly**.

Although this is not penalised, there has often been evidence of confusion in the use of meter and metre!

The project–report should be written in the past tense and impersonal voice. If the project–report is not written in past tense and impersonal voice, eg if written as a set of instructions in the imperative voice, then a maximum of 1 mark can be given for description of how apparatus was used.

Level of demand (3 marks)

There should be three or four experiments attempted corresponding to 10–15 hours labwork. The experimental procedures should be at a level appropriate to Advanced Higher.

Results (8 marks)

Data (1 mark)

Candidates must show all readings and not just the mean values.

Analysis of data (4 marks)

Advantage should be taken of spreadsheet packages to analyse and present data.

All candidates should be familiar with the use of Excel and the LINEST function (or equivalent). LINEST provides a quick method of finding the gradient of a straight line and its uncertainty.

Candidates should show the process of using LINEST using selected cells.

Major and minor gridlines should be shown and graphs should be half page size minimum. The points should be small, but discernible, and error bars should be drawn if possible. The origin should be shown where appropriate.

Straight lines of best fit **should not be forced through the origin.**

All teachers should become familiar with Excel and the LINEST function in plotting and analysing graphs.

Uncertainties (3 marks)

Although the manipulation of uncertainties seems arduous, it is important. All experimental physicists must quote the confidence in their measured values.

Candidates must quote, where appropriate, **calibration, scale reading and random uncertainty** for measurements taken. They should then be combined appropriately.

An example showing how one set of results is combined will be sufficient for each experiment.

Final absolute values in uncertainties should be clearly stated and shown on a graph as error bars, if possible.

Discussion (8 marks)

Conclusion (1 mark)

This must relate to the overall aim of the investigation and be supported by the experimental data.

Evaluation of procedures (3 marks)

This is probably better given at the end of each experiment. The candidate should look at the individual uncertainties and decide on the factor that has had the greatest effect on the readings. They should then suggest improvements. Account should be taken of the plotted graphs and any rogue points should be highlighted.

This is a quality area and candidates should take into account as many factors as possible and suggest improvements to the procedure. It might be that the experiment has systematic uncertainties or indeed is flawed.

Candidates should avoid evaluate comments such as ‘to improve this experiment I would use a better meter or better apparatus’.

Alternatively, the experiment might be successful, but the candidate should highlight the reason(s) for this.

Candidates should refer to graphs, percentage uncertainties and comment on what they show.

Candidates should appreciate the distinction between precision and accuracy. Suggesting that a meter that measured to more decimal places may improve the precision in the measurements but may make no difference to the accuracy of the results.

Evaluation of Investigation (3 marks)

This should be **at the end of the report**.

Candidates have difficulty with this section. An overall evaluation of the report should be given here.

Any frustrations / difficulties encountered should be given. How these were overcome — what improvements / modifications were made? What was gained from carrying out the Project?

Try not to repeat anything that was included in the evaluation of procedures.

State any further work that might be investigated.

Overall quality of project report (1 mark)

Presentation (2 marks)

Title, contents and page numbers (1 mark)

Title, contents and page numbers must be given. Experiments should be written up sequentially. Diagrams and descriptions **should NOT be grouped together.** Avoid using appendices if possible.

Referencing (1 mark)

References **must be cross-referenced in the text** — normally in the Underlying Physics section.

There should be a minimum of **three** different references given written in the appropriate style. The emphasis is on having at least three **different** references, which are also cited in the body of the report, and not just three references to Tyler, A Laboratory Manual of Physics, for example.

Any standard form of citation and referencing is acceptable.

Books: The book title, edition, author and page number should be given, eg [1]Tom Duncan, A Textbook for Advanced Level Students, 2nd Edition, pages 228–229.

Websites: The full URL of the actual page which contains the information should be given and not simply the homepage of the website. Include the date you accessed the material, eg [2]http://en.wikipedia.org/wiki/Young's_modulus accessed on 10/12/2014.

Project Selection

Candidates tended not to attain a high Investigation mark, for the old Advanced Higher, if any of the following were chosen as a main experiment.

- Wind turbines – plastic vanes, adjustable angle, vary number of vanes etc.
- Snell's Law
- Measurement of g using a falling ball
- Speed of sound using two microphones
- Clap – echo method to measure the speed of sound.
- Focal length of a lens using light from a window and screen.

The level of demand for these is not AH level and these experiments should only be used as 'additions' to demonstrate handling of uncertainties**.** It would seem acceptable to include these, **with a good uncertainty treatment**, if the other three experiments are of the appropriate standard. This advice also applies to new Advanced Higher.

Statistical information: update on Courses

Number of resulted entries in 2014	1815

Number of resulted entries in 2015	1845

Statistical information: Performance of candidates

Distribution of Course awards including grade boundaries

Distribution of Course awards	%	Cum. %	Number of candidates	Lowest mark
Maximum Mark - 125				
A	34.7%	34.7%	640	85
B	25.6%	60.3%	472	72
C	17.8%	78.1%	329	60
D	7.0%	85.1%	129	54
No award	14.9%	-	275	-

For this course the intention was to set an assessment with grade boundaries of 62 for the C, 87 for the A and 102 for the upper A. For Q6(a)(iv), a 1 mark adjustment was made to the C, A and upper A boundaries due to the wording of the question. For Q10(a)(iii) (A) and (B) a 1 mark adjustment was made to the C, A and upper A boundaries as they did not discriminate as well as intended.

General commentary on grade boundaries

- While SQA aims to set examinations and create marking instructions which will allow a competent candidate to score a minimum of 50% of the available marks (the notional C boundary) and a well prepared, very competent candidate to score at least 70% of the available marks (the notional A boundary), it is very challenging to get the standard on target every year, in every subject at every level.

- Each year, SQA therefore holds a grade boundary meeting for each subject at each level where it brings together all the information available (statistical and judgemental). The Principal Assessor and SQA Qualifications Manager meet with the relevant SQA Business Manager and Statistician to discuss the evidence and make decisions. The meetings are chaired by members of the management team at SQA.

- The grade boundaries can be adjusted downwards if there is evidence that the exam is more challenging than usual, allowing the pass rate to be unaffected by this circumstance.

- The grade boundaries can be adjusted upwards if there is evidence that the exam is less challenging than usual, allowing the pass rate to be unaffected by this circumstance.

- Where standards are comparable to previous years, similar grade boundaries are maintained.

- An exam paper at a particular level in a subject in one year tends to have a marginally different set of grade boundaries from exam papers in that subject at that level in other years. This is because the particular questions, and the mix of questions, are different. This is also the case for exams set in centres. If SQA has already altered a boundary in a particular year in, say, Higher Chemistry, this does not mean that centres should necessarily alter boundaries in their prelim exam in Higher Chemistry. The two are not that closely related, as they do not contain identical questions.

- SQA's main aim is to be fair to candidates across all subjects and all levels and maintain comparable standards across the years, even as arrangements evolve and change.