May 2018 subject reports

Physics timezone 1

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-13	14-23	24-34	35-45	46-56	57-67	68-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-12	13-22	23-33	34-43	44-55	56-65	66-100

Internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-3	4-6	7-10	11-13	14-16	17-19	20-24

The range and suitability of the work submitted

The range of work submitted was from the basic (e.g. confirming Hooke's law for a rubber band, measuring electrical resistance of putty) to the sophisticated (e.g. measuring the earth's magnetic field, real and theoretical gravity turning points for a water rocket). Some topics, such as the Gauss gun, projectile motion, temperature and viscosity, and resonance of a musical string, were performed many times. Results varied from very poor work to outstanding work. Although the chosen topic is important, how the student approaches the topic and what they do with it is most important for a successful investigation. Most of the investigations were traditional hands on: mechanics, waves, electricity, and fluids were the most popular topics. There were a few database labs, but these followed predictable research questions or copied TSM samples. There were a few computer simulations, some of these also copied existing TSM samples. Some investigations that were not successful were those that included multiple independent variables, investigations that padded their report with two or three separate but topic related investigations, and investigations where the physics background was simply made up by the student when there was established textbook theory. The most successful investigations had well-defined research questions, clearly identified variables and an appropriate means to measure and relate the variables, and an appropriate and known scientific background. Most importantly, the successful investigations were scientifically interesting and relevant to the IB curriculum and showed genuine student involvement.

Candidate performance against each criterion

Personal Engagement Strengths

When a student report demonstrates independent thinking, initiative or creativity, or when there is some personal significance, interest and curiosity relating to the research question, or when there is personal input in the design or implementation or presentation of the investigation, then and only then has the student addressed the criterion of personal engagement. PE is assessed holistically, not in a section or paragraph with the heading Personal Engagement. It was encouraging to see that some students had modified a traditional investigation or designed their own investigation, thus demonstrating independent and creative thinking. Performing an investigation with a standard method and standard analysis but in a thoughtful and competent way often earned one mark for PE. Only the most insightful and thoughtful investigations demonstrated the qualities expressed by the top PE descriptors. Here, students would demonstrate a thorough and detailed analysis, a deep understanding of the issues, and a dedication to quality scientific work.

Personal Engagement Weaknesses

Students would often over-emphasize ‘personal significance’ by writing what seemed to be artificial comments about their interests. Moreover, their background interest would not be related to a specific research question. For example, the love of music is not related to an investigation into the speed of sound. Why then full a page of personal history playing a musical instrument? Teachers need to encourage students to demonstrate their curiosity and insight in the investigation itself, in the nature of the research question, in the details of methodology and analysis, and in other contributions made by the student to their individual investigation. Teachers often over marked PE thinking that an interest in the general topic was enough to earn full marks. Personal engagement in an exploration should demonstrate student input and initiative in the design, implementation or presentation of the investigation, where there is significant independent thinking, initiative or creativity in the work. Because PE is assessed in a holistic way, students must not add a sub-title section “Personal Engagement.”

Exploration Strengths

There were a number of interesting and challenging investigations. These always included a single and well-defined independent variable and a quantifiable dependent variable. Appropriate investigations made use of known scientific concepts and relevant equations, and they would establish a relationship or function between two variables or determine an important scientific constant. Issues of safety, ethical and environmental concerns were mentioned when appropriate. Some successful investigations included variable mass and the Atwood machine, metronome synchronization, wind speed and lift force on a flat roof, the Earth’s magnetic field, temperature and resistance using a Wheatstone bridge, a filament light bulb as a black body radiator. There were some interesting database investigations, including mass-life relationship for stars. Mathematical modelling investigations included a study of rocket launch fuel efficiency and the gravity turning point. Computer simulation investigations included discharge of a capacitor, intensity of reflected light and incident angle, and double-axial symmetry balance analysis. There were also several successful investigations on the nature of large amplitude pendulums where theory and experiment were compared. The key in all of these examples was that the student understood the physics of their investigation and established some relevant and interesting conclusions from data analysis.

Exploration Weaknesses

Assessment of the Exploration criterion was occasionally over-marked by teachers. It is this aspect of an IA that is most important for the possibility of a student's success. Too many times students would select multiple independent variables, perhaps thinking this would enrich the investigation when it fact it inhibited it. Often the known context of a research question was not addressed but would have been helpful to the student to focus and clarify their work. Academic research is expected. Made up physics-like explanations do more harm than good. Historical background is not relevant. Two pages on the history of the guitar when investigating how tension affects the frequency of a guitar string is irrelevant information. Students need to explain their methodology and assumptions as well as the scope and limit of their investigation, but they do not need to give pedantic step-by-step instructions. There were numerous investigations about viscosity and temperature, projectile motion without any depth of understanding, formation of craters, and the most popular of all, refractive index of water with salt or sugar solution. A number of students were fascinated by the Gauss gun and attempted mediocre investigations. Please make sure students understand the topic they want to study. There were some meaningless investigations too: relating the distance covered by a wheel in one rotation as a function of the wheel diameter; investigating how the time to run up a flight of stairs relates to the power exerted; or how mass affects the moment of inertia. In these cases, the independent variable is also the assumed dependent variable.

Analysis Strengths

Analysis includes the traditional scientific skills that assess data collection, data processing, appreciation of errors and uncertainties, the scope and limit of the data, graphing and methodological issues. Most students demonstrated a sound mastery of analysis. The majority of students demonstrated the ability to obtain and record data, including raw uncertainties. In most cases, data tables were clear and consistent with scientific notation. Processing was often detailed, with sample calculations of complex computations. Samples of simple calculations are not required. Graphs were nicely presented often with error bars. Most student graphs were computer generated, and in most cases known theory directed the appropriate graph representations. Occasionally students used more advanced methods of error analysis, and this was successful.

Analysis Weaknesses

Some data tables were confused and hard to understand. Column headings should include the quantity, units and uncertainty with units. Some graphs lacked appropriate detail, and others were too small to appreciate or had too much information entered on a single graph. The terms 'proportional' and 'linear' were not always understood correctly. The construction of minimum and maximum gradients, when the gradient was meaningful, was often done in an unrealistic and extreme way. Students need to appreciate what their data does and does not reveal. A number of times a student graphed relevant data where the data scatter suggested a curve and yet the student forced a linear fit. The linear fit was then used to establish a bogus conclusion. Often a forced linear fit would imply a meaningless or impossible physical result when one axis quantity was zero. In most cases, graphs should have zero-zero origins. There were occasional inconsistent expressions of significant figures. What is the physical meaning of an uncertainty of 27.853%? The general rules should apply: (1) No calculation can improve precision. The result of addition and/or subtraction should be rounded off so that it has the same number of decimal places (to the right of the decimal point) as the quantity in the calculation having the least number of decimal places. That is to say, a sum or difference is not more precise than the least precise number. (2) Significant figures in the result of multiplication and/or division should be rounded off so that it has as many significant figures as the least precise quantity used in the calculation. A product or quotient has no more significant digits than the number with the least number of significant digits. Teachers need to ask students to understand what they are saying. Occasionally students would fill pages with formal or purely mathematical error analysis without reference to the physical meaning of their data. The focus needs to be on physics.

Evaluation Strengths

The evaluation criterion remains one of the most demanding. Teachers often over-mark this criterion. Students should describe in detail and justify a conclusion for their investigation based on the original research question and their data analysis. Focus is the key here. Appreciation of the quality and range of data should be included. The propagation of uncertainties is relevant. When there is a known scientific context or accepted value, then students need to compare their result with the accepted value. When there is no such value then a reasonable interpretation of the accepted scientific context should be given. For example, a student claimed that the refractive index of water at 85°C was 5.2. The student never thought this might be wrong, as their data was thought to show this. Another difficult component of the evaluation criterion is an appreciation of the strengths and weaknesses of the methodology involved in the investigation. The more successful student reports showed an appreciation for any assumptions of their methodology. Finally, students need to suggest realistic and relevant improvements as well as possible extensions of their investigation. These need to be specific and based on an evaluation and appreciation of the weaknesses or limits. Significant improvements can be understood as an extension.

Evaluation Weaknesses

Often students stated they ‘proved’ their hypothesis about their research question without re-stating it in the context of their data and methodology. An appreciation of the scope and limit, the methodology and any theoretical assumptions should be addressed when evaluating a conclusion. Too often students made general and qualitative comments only: “I am pleased with my results; I proved my hypothesis.” Often students would construct a meaningless polynomial equation to fit their data and then assert a conclusion described by the equation, without giving any physical meaning to the results. If the student had extended the graph they would have seen the senseless meaning of such an equation. Students need to appreciate the physical meaning of the quantities under investigation, and so they need to interpret the data correctly. The graph of one student investigating mass and period of a SHM oscillator claimed that with zero mass the system would oscillate with a period of 4 seconds. There is more to a graph than a simple equation. Finally, evaluations were often superficial, blaming human error or friction, or systematic error when the best-fit line was an inappropriate and meaningless line fit. Suggesting a more precise rule would result in more accurate measurements seems artificial.

Communications Strengths

The Communications criterion more often than not successfully earned marks in the 3-4 mark-band. Communications, like Personal Engagement, is assessed holistically. This means that the overall clarity, flow and focus of the report are assessed. The best reports made it clear in the first paragraph what the specific investigation was about, how it was conducted and what results were found. The best reports stayed focused on the research question and related physics and did not ramble on with generalities about the student's interest, historical background or unnecessary pedantic details. The best reports had descriptive titles, like "How temperature affects the refractive index of water" and not titles like "Bending light" or "Bouncing balls." The majority of reports used correct and relevant scientific notation, equations and units. MS Word has a built-in equation editor, and students are expected to present equations properly. The majority of reports were within the 12-page expectation. It has becomes clear that ten pages is a perfectly reasonable length for a focused and concise IA report. Occasionally, however, an extended report flowed well and wasted no space, and as such, for example, a 16-page report was not penalized under Communications. Reasonable margins, spacing, appropriate scales of graphs and data tables, all help the communications criterion. It is best to avoid 8-point font and single-spaced text. Most students consistently and appropriately provide references to their work (in a variety of consistent and acceptable ways). Any picture image copied from a source must be referenced, not just a listing in the bibliography. Academic research is expected. Research questions and hypotheses need to be supported by relevant scientific information, relevant to the investigation and not just historical background.

Communications Weaknesses

A number of students omitted any sort of investigation title. Titles should be descriptive. For example, "Using a conical pendulum to determine gravity" is appropriate but a title like "Gravity" or "Physics Investigation" is not appropriate. A cover sheet or title page is not necessary. A table of contents may give the reader an overview but is not necessary either. Several pages of the history of physics or standard textbook theory not directly related to the research task wastes space and demonstrate a lack of focus. Although the moderator needs to know how the student performed the investigation, they do not need simplistic and obvious comments like: "Set up the equipment, turn on the computer….." Often students include photographs when a clear sketch would have been better. Colour photographs of a metre rule, or a stopwatch, or electrical wires do not help the understanding of the work and is a waste of space; superfluous text distracts the reader from the flow and logic of the investigation. A good individual investigation does not need to resemble a cookbook approach. Too often images taken from books or the Internet were not referenced. Communications does not penalize for lack of references but rather when this occurs it becomes a serious IB issue of academic honesty and possible plagiarism. Simply listing a number of texts or websites at the end of the report without using them is not referencing. Some students padded their investigations with artificial research references that were never used.

Recommendations for the teaching of future candidates

- It is important that teachers provide guidance during the entire IA investigation process, and not only when they read a draft.
- Students need to acknowledge and appreciate the physics that is already known about their research question. Too often students made up common sense physics or failed to appreciate well-known theories.
- Teachers should encourage students to include a descriptive title to their report and to make sure the research question is identified and explained within the first paragraph. A title page or a table of contents is not necessary when a report is concise and focused.
- All images (pictures, diagrams) and any ideas that are copied must be referenced. A bibliography at the end should only include sources that were actually used and properly referenced within the text.
- Research questions are most appropriate for assessment when they address a function or relationship between two variables, or where they experimentally measure an important constant in nature. Research questions should be both challenging and scientifically interesting. The purpose of the investigation can be expressed as a research task, and not necessarily in a form of a question.
- Students should not assume that data scatter graphs must be forced into a best-fit linear line. In many cases the physics meaning of doing this goes against known theory and common sense. For example, one student forced a linear line fit on a Newton cooling curve graph. If, however, a proper function is found then such quantities can be graphed in a linear graph. Computer fitted polynomials can fit any data scatter, and students need physical reasons for selecting a complicated best-fit line.
- It is important that students have a sound knowledge of the assessment criteria. Teachers can discuss extensions to class investigations or ideas relating to topics studied throughout the school year, so when students are expected to come up with their own research topic, their minds are full of exciting possibilities.
- Make sure students use physics terms correctly. The change in temperature is not temperature, velocity is not average speed, distance is not displacement.
- Students should not copy existing IAs as published by the IB as teacher support material or follow detailed worksheets as published by commercial IB support companies or purchase so called teacher marked IA reports.

Further comments

- Teachers application of the assessment criteria is mostly in line with IB standards, but occasionally, when teachers' over-mark or under-mark the student's script, then the examination team needs to moderate the student's total. When this happens, the schools receive feedback. If the teacher's assessment is within tolerance, however, then there is no feedback to the school.
- When teachers upload a student's IA and enter criteria marks there is additional space for entering comments about their assessment of the student's work. Teachers should take advantage of this aspect and share with the examiner their reasons or evidence for the awarded marks. Alternatively, teachers can add comments throughout the report or, preferably, at the end of the report. It is best not to simply copy the official five pages of IA criteria and checkmark the assessed levels.

- Teachers should realize that issues of uncertainty and error analysis appear under the Exploration, Analysis and the Evaluation criteria. However, each time the issues are addressed from a different perspective. In Exploration, students should take into consideration significant factors that may influence the quality of work. Under Analysis, students need to appreciate the impact of uncertainties, and this is a quantitative appreciation. Under Evaluation, students should discuss the limitations of the data, as well as the sources of errors and uncertainties.
- Under the criterion of Evaluation, procedural and methodological issues are distinguished. Procedural issues (mark band 1-2) are a fixed set of steps, not a generalization. They are a subset of methodological issues. For example, taking more data, or extending the range of data, are both procedural issues. In mark bands 3-4 and 5-6, methodological issues are mentioned, and these issues address the assumptions in the method, and may include suggestions on new ways to measure the quantities or alternative approaches to the research question.
- For the May 2018 exam session, Standard Level IA totals earned on average between a high grade 4 to low grade 5, while Higher Level IA totals earned on average from a low grade 5 to a high grade 5.

Paper one

Component grade boundaries

HL

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-12	13-15	16-19	20-22	23-26	27-40

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-9	10-11	12-13	14-16	17-18	19-30

General comments

A proportion of questions are common to the SL and HL papers, with the additional questions in HL providing further syllabus coverage.

A higher percentage of G2s were submitted this year compared to last year, however the response rate is still well below 50%. For SL, there were 91 responses from 558 centres and for HL there were 44 responses from 361 centres. While this return rate may indicate a general level of satisfaction with the papers, we strongly encourage teachers to take the time to provide us with thoughts about the papers and the individual questions. The G2 comments are always carefully considered and they do inform the grade award process and future writing.

The HL (SL in brackets) paper was regarded as being of appropriate difficulty by about 75% (70%) of the respondents with 25% (30%) finding it too difficult. The HL paper was deemed to be a little more difficult than the previous year's paper by 50% of respondents, although 36% of HL respondents did judge it to be of a similar standard. For the SL paper, 42% of respondents felt the paper was of a similar level of difficulty as the previous year's paper, with 29% considering it a little more difficult. The clarity of wording also showed some difference between the SL and HL paper, with 59% of HL respondents feeling that the paper had good or better 'clarity of wording', while 70% of SL respondents reported the same level. Presentation of the paper was judged as good or better by 75% (83%) of respondents.

There was a feeling expressed in the G2 comments that this paper required more higher level thinking than in the past as a result of more challenging, often multi-step, questions. It was also suggested that a number of questions tested multiple concepts or required significant equation manipulation; any of these factors may have led to time being more of an issue this year for students as they worked to complete the paper. (See discussion of 'Time' and 'Trickiness' below.)

There was some concern that certain questions were wordy and long, which would present a particular challenge for second language learners.

There were only a few G2 general comments. Question-specific comments will be dealt with later in this report.

Time

The syllabus specifies that 50% of multiple choice questions will require AO3 skills and students should expect some questions to be answered in well under a minute allowing extra time for questions of greater complexity.

There is evidence from the number of blanks that both SL and HL candidates may have struggled a bit with finishing the paper in good time. It should be noted that the common elements of the curriculum need to be taught to the same level of complexity and will normally be tested with the same multiple-choice questions. In this session there were 17 common questions which is in line with previous practice.

Trickiness

It is not the intention to 'trick' students, but students cannot expect multiple choice questions to follow a familiar pattern. It is important that students read all questions carefully and expect them to be different from those asked in previous years.

Physics involves the application of general principles to new situations. There is very little that needs to be memorized in physics; instead time should be spent applying the underlying core ideas to observed phenomena. Sometimes, for example, a problem can be solved by a consideration of the relative magnitude or units of the responses rather than a detailed working of the algebra.

Other comments will be dealt with in the item analysis below.

Statistical analysisHL

International Baccalaureate

Multiple Choice Analysis Report

PHYSICS HL PAPER 1 (MCQ) Timezone 1 MAY 2018 In Question order

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	656	1664	354	652	4	49.97	0.51
2	1822	769	510	206	23	54.71	0.47
3	478	1847	795	208	2	55.47	0.31
4	1600	563	675	465	27	48.05	0.48
5	571	61	73	2615	10	78.53	0.33
6	606	247	679	1797	1	53.96	0.57
7	621	488	1450	763	8	43.54	0.33
8	885	604	1703	124	14	51.14	0.45
9	1410	1198	351	358	13	10.75	0.14
10	1496	257	1397	177	3	44.92	0.29
11	1121	467	853	874	15	26.25	0.39
12	873	685	809	957	6	28.74	0.33
13	1178	845	981	301	25	35.38	0.31
14	416	2230	373	305	6	66.97	0.46
15	1188	615	1122	379	26	33.69	0.44
16	1134	575	811	800	10	34.05	0.42
17	1588	125	1424	187	6	42.76	0.27
18	1953	783	372	210	12	58.65	0.35
19	1469	991	468	391	11	44.11	0.41
20	208	619	2276	211	16	68.35	0.48
21	2161	134	378	648	9	64.89	0.42
22	672	1273	974	392	19	38.23	0.36
23	69	1825	1029	397	10	54.80	0.23
24	1200	492	1069	558	11	36.04	0.35
25	2379	353	513	79	6	71.44	0.40
26	163	2133	626	401	7	64.05	0.47
27	862	739	1267	420	42	38.05	0.26
28	635	908	1449	317	21	43.51	0.33
29	694	555	1193	873	15	35.83	0.20
30	1498	621	430	763	18	22.91	0.18
31	451	799	369	1698	13	50.99	0.35
32	1061	869	840	520	40	31.86	0.23
33	294	1635	1213	172	16	36.43	0.08
34	1411	1374	270	263	12	7.90	0.10
35	483	507	1499	802	39	45.02	0.27
36	1476	951	609	260	34	44.32	0.33
37	186	377	730	2008	29	60.30	0.47
38	927	918	762	680	43	27.57	0.13
39	634	609	1129	920	38	27.63	0.23
40	968	1078	941	306	37	32.37	0.06

Number of candidates : 3330

SL

International Baccalaureate

Multiple Choice Analysis Report

PHYSICS SL PAPER 1 (MCQ) Timezone 1 MAY 2018 In Question order

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	951	**1978**	635	1499	13	38.97	0.53
2	634	432	**3815**	191	4	75.16	0.40
3	**2135**	1420	957	494	70	42.06	0.50
4	994	**2570**	1043	465	4	50.63	0.33
5	**2036**	993	1273	723	51	40.11	0.42
6	1263	83	204	**3515**	11	69.25	0.46
7	1099	2652	**915**	396	14	18.03	0.27
8	1025	428	604	**3009**	10	59.28	0.42
9	110	**877**	573	3512	4	17.28	0.18
10	**1743**	713	2225	375	20	34.34	0.31
11	1388	1047	**2301**	324	16	45.33	0.31
12	1566	2290	750	**450**	20	8.87	0.08
13	2172	724	1259	**888**	33	17.49	0.27
14	1474	1000	1488	**1094**	20	21.55	0.21
15	447	442	**3925**	247	15	77.32	0.19
16	1048	**2721**	586	703	18	53.61	0.44
17	538	1634	581	**2316**	7	45.63	0.44
18	**1183**	831	1537	1506	19	23.31	0.28
19	**1396**	1274	1282	1097	27	27.50	0.36
20	1651	638	**1462**	1303	22	28.80	0.29
21	1295	2090	884	**776**	31	15.29	0.29
22	**2529**	1213	722	554	58	49.82	0.39
23	1817	585	**1581**	1064	29	31.15	0.39
24	**1815**	1638	917	678	28	35.76	0.40
25	458	1211	**3023**	337	47	59.55	0.47
26	1173	922	540	**2393**	48	47.14	0.29
27	293	2251	**2164**	343	25	42.63	0.48
28	1025	**1462**	1735	787	67	28.80	0.35
29	1227	**2748**	418	646	37	54.14	0.28
30	**3068**	717	1049	181	61	60.44	0.47

Number of candidates : 5078

The overall performance of candidates and the performance on individual questions are illustrated in the statistical analysis of responses. These data are given in the grids below. The numbers in the columns A-D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank.

The question key accepted answer is indicated by a shaded cell.

Comments on the analysis

Difficulty

The *difficulty index* (perhaps better called facility index) is the percentage of candidates that gave the correct response (the key). A high index thus indicates an easy question.

Ignoring a couple of outliers, the difficulty index varies from about 23% in HL and 17% in SL (relatively ‘difficult’ questions) to about 79% in HL and 77% in SL (relatively ‘easy’ questions). The papers gave a reasonable spread of marks while allowing all candidates to gain credit.

This range of indices showed that the paper was accessible to students of all abilities. In both papers, there was an even range of difficulties amongst the questions, which led to a normal distribution of marks. This meant that both papers were effective assessment tools with the mean mark being broadly like the previous May.

Discrimination

The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates.

All questions had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. Six HL and three SL questions fell below this standard. However, a low discrimination index will not always result from an unreliable question. It could indicate a common misconception amongst candidates or a question with a high difficulty index.

‘Blank’ response

In both papers, there were a number of blank responses throughout the test with a noticeable increase toward the end as in previous years. This supports the observation on the G2 forms that some candidates had insufficient time to complete their responses. In other cases, candidates will have left blank the questions they were unsure of. Candidates should be reminded that there is no penalty for an incorrect response. Therefore, if the correct response is not known, then an educated guess should be made. In general, candidates should be able to eliminate some of the ‘distractors’, thus increasing the probability of selecting the correct response. As indicated above, in certain instances the correct response can be selected through a consideration of relative magnitude or units of the responses rather than a detailed working of the algebra. In this manner, there should be adequate time to complete all the questions and check any uncertain responses.

The strengths and weaknesses of the candidates in the treatment of individual questions

SL & HL Common Questions

1 HL, 1 SL

This question was generally well answered, however a number of candidates seemed to confuse fractional uncertainty with calculating volume itself (leading to answers A & D).

2 HL, 3 SL

There were concerns expressed in the G2 forms around the use of g here. For publication we have amended the answers so that speeds are given in the more conventional m s^{-1}. .

3 HL, 4 SL

Candidates need to recognize that the descriptor smooth implies a frictionless surface. The distinction between the two surfaces as rough & smooth should suggest to candidates that the wall is frictionless while there is friction between the ladder and the floor.

4 HL, 5 SL

Without careful reading, candidates might assume the ratio is for both energies at h/4, leading to an incorrect answer.

8 HL, 11 SL

Units in responses were given as k rather than K. For publication, we have amended the answers to the correct unit.

9 HL, 12 SL

This question had a particularly low difficulty index, indicating that the majority of candidates selected an incorrect answer. The most common (incorrect) answer was A, which was close to the solution obtained through the incorrect use of PV = nRT. However, in order to use this formula, the N (number of molecules) in response A would have to be n (number of moles), and N is clearly expressed in question stem. Furthermore, N cannot be used with R, which is also present in response A. The challenge here tends to be the result of overthinking the question; this is an instance where students should look generally at all responses in order to determine the correct one rather than trying to derive the answer.

10 HL, 10 SL

Many students incorrectly selected response C, which would be correct if the x-axis was in Kelvin.

HL 11, SL 13

Response A was a common incorrect answer, the result of assuming wavelength = 3.0 m rather than lambda/4. The guide is clear that the first harmonic is n=1, and so this should not have presented a particular difficulty.

HL 16, SL 18

Some candidates had difficulty interpreting the circuit diagram, with some treating all three resistors as if they were in series, while others considered only the two, three ohm, resistors.

HL 19, SL 24

Response B was a common incorrect answer, despite the incorrect arrow direction for positron and the presence of an antineutrino rather than a neutrino). Candidates did not need to consider time in this instance as it over complicated the analysis.

HL Only Questions

6

This question was generally well answered, however some candidates solved for net force or momentum rather than upward force.

7

The fact that the mass was given in grams appears to have been missed by a number of candidates, leading to a POT error.

15

A significant number of candidates selected response A, perhaps mistaking E for k in the formula V = kQ/s. It would be useful for candidates to look at units to help determine the correct answer.

17

Many candidates appear to have assumed that current remained constant in the two situations; this assumption would produce response A as a result (P and R directly proportional), which was a common error.

24

Only one statement correctly describes GHE; the graph is not necessary to correctly answer this question and was perhaps confusing for a number of candidates.

30

Many candidates incorrectly selected response A, likely confusing electric potential with electric field.

33

The majority of candidates recognized that the direction of force would change when opening compared to when closing, however many incorrectly selected response B here.

The discrimination index is very low for this question, suggesting that candidates successfully eliminated two wrong answers, but then randomly chose between responses B and C (perhaps due to timing of the paper).

34

This question had a high difficulty index. Most candidates selected responses A or B, recognizing a change in current would occur, but many were unclear whether it was an increase or decrease. Few candidates recognized the phase shift that would occur between current in the primary vs. secondary coil. This question might be a useful teaching point, since it was surprising that few candidates selected responses C or D.

38

Candidate answers were fairly evenly distributed among responses. This question would be useful when teaching students about the spacing of energy levels in diagrams.

SL Only Questions

7

This is a good example of a question that can be difficult to solve, but is easy to reason through to get the correct answer. This question had a very low success rate, and a relatively low discrimination index. Candidates almost equally chose response A and B.

9

Candidates overwhelmingly chose response D, and there was a low discrimination index which indicates that stronger candidates were missing this as much as weaker. The term “rate of change” may be problematic for many candidates, and so this question might be useful as a teaching point.

19

Candidate answers were distributed among all four answers. Careful interpretation of the diagram is needed here.

20

This is another example of a question that can be a difficult to solve mathematically, but is pretty easy to work out conceptually (based on currents). Candidates clearly struggled, with the majority (incorrectly) choosing response A.

23

Very few candidates correctly selected response B, indicating a need for greater preparation around the nature of science (NOS).

Recommendations and guidance for the teaching of future candidates

Multiple choice items are an excellent, motivating and highly time-efficient way of testing and promoting learning while a course is being taught. They can be used as warm up questions to stimulate discussion as well as for quick tests and should never be regarded as add-ons only to be practiced, a paper at a time, for the final examination.

Well-constructed multiple choice questions can be very beneficial in addressing student misconceptions about a particular topic. Looking through many of the questions on these papers it is easy to see that candidates who did not fully understand the topic or who held a common misconception would choose a particular answer over the correct response. This can be a very useful teaching tool, particularly when that information can be aggregated to determine how the class as a whole is understanding a particular concept.

Arithmetically the students should be adept at dealing with powers of ten quickly and efficiently. Total reliance upon a calculator for simple cancelling and combining the powers of ten can be a waste of valuable time. Overreliance on a calculator can also cause candidates to potentially panic on this paper when they are faced with a calculation in a question. The non-calculator mathematical skills of cancellation, mental arithmetic and dealing with powers of ten may need to be taught explicitly to students.

Teachers frequently comment on unfair 'tricky' questions. In order not to be 'tricked', candidates must read the question very carefully to visualize the situation. This visualization will involve stepping back from the question and understanding what is happening. It can start with thinking about what core physics concepts are involved in the situation and what the candidate knows about those concepts. Plunging into the minutiae of a question or scouring the data booklet without first thinking about these steps first can cause students to fall into traps rather than see the correct answer.

There is no single most successful strategy with MCQs, so flexibility of thinking is needed. Students should be encouraged to develop strategies for spotting the correct answer - rather than working it out as they would in a paper 2. Among the strategies leading to successful completion of multiple choice questions are:

- Eliminate the clearly wrong responses.
- Consider the units. Paying attention to units can sometimes lead to the identification of the correct response.
- Exaggerate a variable - this will often point the candidate in the correct direction.
- Draw or visualize the situation while reading the stem. A simple sketch will aid in understanding and often lead the candidate to the correct response. This is particularly important for students who are not testing in their native language.
- Distinguish between cos, sin and tan functions - mentally making the angle 0° or 90° will often show which is correct.
- Use proportion: new quantity = old quantity x a fraction, where the fraction depends upon the variables that have changed.
- Observe the axes on graphs and use units to attach meaning to the gradient and the area.
- If all else fails, make an intelligent guess.

Candidates should try every question. It should be emphasized that an incorrect response does not give rise to a mark deduction.

The stem should be read carefully to identify or highlight key words or phrases. Inevitably some questions may appear at first sight similar to past questions, but students should not jump to conclusions. It appears that some candidates do not read the whole stem but rather, having ascertained the general meaning, they move on to the options. Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important. They should also bear in mind that they are asked to find the **best** response. Sometimes it may not be strictly 100% correct but physics candidates should be used to identifying and ignoring quantities that have negligible impact.

Candidates should consult the current *physics guide* during preparation for the examination, in order to clarify the requirements for examination success. Teachers should be aware that questions are constructed from the requirements of the syllabus - not from previous papers.

The guide does invite the candidates to recall certain simple facts, although most of physics is process oriented. Occasionally there are items in physics that need to be memorized but the students should not expect to find many multiple choice questions based purely upon memory. That said, student understanding of core concepts and definitions often impacts how they read and answer multiple choice questions; for example, the topics of nuclear binding energy and the photoelectric work function where critical in correctly answering questions on this paper. It is also worth noting that current specifications require that about 50% of the items will be AO3 questions involving higher order thinking skills.

Candidates can expect the proportion of questions covering a particular topic to be the same as the proportion of time allocated for teaching that topic, as specified in the physics guide.

Paper two

Component grade boundaries

HL

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-24	25-36	37-47	48-59	60-95

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-9	10-15	16-20	21-26	27-31	32-50

General comments

This was the third May assessment for the new course and there was evidence that this year’s candidates are more at home with the changed demands of the course.

The G2 comments were generally favourable for both papers. At HL (SL in brackets) 44 (91) schools responded – a very small number given the number of centres assessing in Physics. Teachers are strongly encouraged to fill out the G2 forms each session. 86% (76%) of respondents felt the paper was at an appropriate level of difficulty. 63% (74%) found the paper of a similar or easier standard than in 2017. Clarity of wording and presentation of the paper were both found to be good or better by 60% (75%). Many teachers regarded the papers as having interesting contexts and to represent the type of paper that should be set for candidates at this level. Only around 10% (13%) found minor issues with accessibility.

At HL there was some evidence that candidates were short of time on the paper, with the last few questions on the paper being left blank more often than others. There were no dead marks on the paper and excellent attainment was seen from some candidates who wrote and evaluated at a high standard. In the work of these candidates, calculations were often clear and laid out in a very satisfactory way. However, this was not seen from all. There was the usual negligence in respect of units and candidates need to continue to work at this aspect of examination technique.

At SL the standard was more mixed. There were clearly some candidates who had a good grasp of the subject matter and could express it concisely, but far too many candidates struggled with the construction of a reasoned argument and its presentation.

Candidates at all levels would be well advised to take note of the command word in a question and try to demonstrate their very best physics when answering questions. In their own interests, candidates should write with precision and care.

This effective presentation of work is a skill with which many candidates struggle. Examiners cannot give credit for illegible statements. Work – whether written, algebraic, or numerical answers – is often poorly conveyed. The order of written material is ill-considered; numerical solutions are jumbled and incoherent. The standard of work is in many cases very poor indeed. Candidates are given enough space for answers provided they seek to lay the work out in a neat and obvious way. Numbers are frequently illegible to some degree. The numerals 4, 7 and 9 are often written so poorly that they are indistinguishable; powers of ten are poorly written – examiners will not give the benefit of the doubt in such cases. They should seek to lay out work in a clear and unambiguous way, they should seek to write legibly, and they should ensure that the final answer is clear and obvious. These are small points that will gain some candidates many marks.

Some candidates continue to work outside the scanned area (denoted in all case by the boxes rules around the answer lines and other working areas). When examiners see material sliding off into un-scanned areas or are directed to it by the candidates then they will do everything possible to find the answer. However, if invisible off-scan work is not flagged up, then examiners cannot be blamed for failing to consider it in the marking. The instructions to candidates are very clear on this point.

Where a candidate is asked to 'show that….' examiners require a reasoned argument within the context of the question leading to the desired result. All algebra must be clear as well as any substitutions made. The answer should be given, in this case, to one more SD than declared in the stem to indicate that a calculation has been made as the final step in the argument.

When asked to “calculate” candidates should also give steps in a logical progression. It is only in this way that the candidate can guarantee to receive compensatory credit for errors that occur in the middle of the work. Thus, many candidates miss out on errors carried forward through this type of poor communication both within and between sub-sections of questions. It is not the role of the examiner to investigate the origin of mysterious numbers that appear and disappear in work. It is the candidate’s job to communicate clearly.

When asked to “explain” candidates should think about how an expert in the field would go about explaining a concept or a phenomenon. Candidates should use clear, precise, correct terminology and lay the explanation out in a proper order. Too many candidates used vague terms and very loose language to answer these types of questions and often received few marks as a result.

Most calculations in Physics proceed from an equation that often needs to be re-arranged from a version in the Data Booklet. Then a numerical substitution is required before final calculation. These stages are, ideally, written beneath each other in a logical order. At both HL and SL, examiners find that too many candidates present a jumble of unrelated algebra and numbers with an answer appearing in some random position. Candidate who present their work in this way do themselves no favours.

The areas of the programme and examination which appeared difficult for the candidates

- drift speed
- photoelectric effect
- diffraction and interference patterns
- nuclear decay

The areas of the programme and examination in which candidates appeared well prepared

- basic thermal calculations
- calculations in the mechanics section
- transformers, both calculations and their use

The strengths and weaknesses of the candidates in the treatment of individual questions

1a HL, 1a SL

This question was well answered in general.

1b HL, 1b SL

This first part of this question was well answered in general. This second part may have confused candidates because of the fact that they were asked to draw in a resultant force vector and not a traditional free-body diagram. Stronger candidates drew one long upward vector, while weaker candidates added other forces in - many of which did not make sense in this context (such as a normal force). While not a traditional question, the candidates were not being asked to construct a free-body diagram, but instead were being asked to draw a scaled vector. The third part of the question was generally well answered with a few candidates getting the force summation backwards. Some candidates clearly confused the tension in the rope with the resultant force previously calculated.

1c HL, 1ci SL

Candidates generally had the correct idea, but failed to use proper names for the types of energy using more generic phrases like “Potential energy converts to kinetic energy” rather than referring than using a full proper name like “gravitational potential energy”. For the second part of the question, like the first, some candidates did not use the proper names of the types of energy - this was particularly problematic in this question because of the two different types of potential energy present. Additionally, because there were two objects candidates were expected to link the type of energy to a specific object (kinetic energy of the box, for example).

1d HL, 1d SL

Many candidates made the link between elastic constant and the elastic potential energy equation, but few fully explained how conservation of energy could be properly used. A few candidates approached this as a force/Hooke’s law question even through the prompt was specifically about energy.

1e HL

This was a challenging question for candidates. Very few recognized this was a simple harmonic motion problem, and so most tried to apply a kinematics solution assuming a constant acceleration. For the second part, while many candidates continued with constant acceleration attempts similar to the previous question, some did successfully apply the conservation of energy to determine the correct final velocity, and a small number successfully applied the SHM equations to solve for velocity.

2a HL, 2a SL

This question was well answered in general.

2b HL, 2b SL

This question was well answered in general with the occasional power of 10 error. The second part of this question was challenging for candidates for two reasons; candidates needed to select the correct formula as well as convert the given temperature to kelvin. A number of candidates incorrectly attempted to solve for energy using the kinetic energy formula. Weaker candidates confused temperature with average kinetic energy and gave an answer in Kelvin.

For the final part of the question on the HL paper few candidates determined a correct solution. Many were able to earn a mark for determining one of the steps in the solution, though.

2c HL, 2c SL

Many candidates were able to discuss this from a microscopic view and successfully connected temperature to speed of gas molecules and pressure to collisions with walls. However, some attempted to simply cite PV=nRT and suggest that pressure is therefore related to temperature. This approach was awarded zero marks.

3a HL, 3a SL

Most candidates were able to make the connection between destructive interference and dark fringes, but many gave very vague, general responses about this. The command term "explain" requires more detailed information than many candidates provided. On the HL paper, few candidates demonstrated an understanding of the concept of coherence and its connection to interference patterns. On the next section the interference questions were a challenge for candidates, and there seemed to be much confusion about which equation to apply to which circumstance. Even when using the correct equation, many candidates neglected to double the distance provided when determining y.

3b HL

As with the previous interference question there were many creative attempts at a solution. It is worth noting that there was a mark assigned for writing an answer with the proper number of significant digits. Candidates can be awarded this mark regardless of whether or not the answer is correct. The next part of the question was left blank by many candidates, and those that attempted it did not earn full marks. One source of issues for candidates was recognizing that the angle used in this calculation needs to be in radians, not degrees. This is another indicator that candidates are not as comfortable with the equations for interference.

3c HL

This was generally well answered, with a few candidates reversing the wavelengths and ending up with the earth and galaxy moving towards each other. Many candidates also mentioned the Doppler Effect which was not required but was good to see.

3d HL, 3b SL

This question was surprisingly difficult for candidates, and very few were successful in calculating the new wavelength. The second part of the question was addressed with mixed results. Some candidates clearly did not understand what the question was asking and gave very general responses about how to change an interference pattern (such as changing the slit width) and others took a very generic approach about possible changes (such as the intensity might increase or decrease). The final part of the question was addressed with mixed results. Some candidates clearly did not understand what the question was asking and gave very general responses about how to change an interference pattern (such as changing the slit width) and others took a very generic approach about possible changes (such as the intensity might increase or decrease). Candidates should be reminded to read the question carefully before writing a response.

4a HL, 4a SL

Candidates generally chose the correct equation for this, but there were many power of ten errors.

4b HL, 4b SL

As with 4a, there were many power of ten errors in this calculation. Additionally, many candidates calculated speeds that were far outside the bounds of reasonable (powers of ten in the twenties). For SL candidates, there was a mark assigned for writing an answer with the proper number of significant digits. Candidates can be awarded this mark regardless of whether or not the answer is correct.

4c HL

This first part of this question was not well answered by candidates. For the second part while many candidates skipped this question, a significant portion made some attempt at a solution. We allowed a variety of approaches that allowed candidates to be awarded at least some marks.

5a HL, 5a SL

There was a wide variety of answers here, many incorrectly stating that the field was circular (clockwise/counter-clockwise) or tangential to the circular path.

5b HL, 5b SL

This question was well answered in general. However, some candidates incorrectly used a value of 1 for q rather than the proper charge on an electron.

5c HL, 5c SL

In this “explain” question, candidates needed to demonstrate an understanding of the importance of the relationship between the direction of magnetic force and the direction of electron travel. Candidates were required to specify that the relevant force was magnetic (rather than the more generic “net” or “resultant” force). In the second part of the question candidates generally recognized that the electron was experiencing a centripetal force/acceleration and so earned a mark. Many candidates compared the direction of the magnetic force with the direction of electron travel rather than specifying that it was the fact that the magnetic field and electron velocity being at right angles that produced the circular path.

6a HL, 6a SL

On the SL paper this question was well answered in general. However, on the HL paper this question was not well answered. A surprising number of candidates switched the labels on the electron.

6b HL, 6b SL

Many candidates correctly identified the general shape of the curve but precision around where the lines cross (0.050No) and/or the final vertical height of the B curve (around 0.80No) was often lacking. The second part of the question was addressed with mixed results. Candidates were not awarded credit for simply recognizing that 1.4 is one-third of 4.3. Key to solving the problem was the recognition that the fraction of Be remaining was ⅛. Following this, candidates determined that three half-lives had passed either by using logarithms or recognizing $(½)^3$ = ⅛. Many candidates failed to include an additional significant figure when determining half-life, which was required to show the exact value obtained from their calculation. The final part of the question was generally well answered on the SL paper but was a challenging question for HL candidates.

6c HL, 6c SL

For the first part of the question few candidates recognized that thermal radiation was a form of EM radiation; most referred to heat transfer. On the second part many candidates recognized that the universal wave equation could be used with Wien's law, using frequency to determine temperature. The third part of the question was left blank by many candidates, but those who attempted to answer it did well. A few candidates neglected to convert temperature for Celsius to Kelvin. On the HL paper, of the third part of the question some candidates were able to specify the direction of energy transfer, but it was clear that they did not fully understand that they were being asked to name and describe an actual method of energy transfer. Finally, on the last part of the question a number of candidates found the unit identification challenging. It was common for candidates to correctly identify the units for intensity, for example Wm^{-2} or $Js^{-1}m^{-2}$, but then neglect to convert these units to fundamental SI units as required for MP2.

7a HL

This question was generally well answered.

7b HL

Many candidates were able to calculate the charge on the capacitor (although there were many who did not correctly convert the capacitance in picofarads). Fewer candidates were able to correctly identify the charge as negative (many simply did not specify a charge).

7c HL

Many candidates correctly identified that the charge would increase and connected this to the change in capacitance. However, very few correctly stated that the potential difference would remain constant, and therefore were not awarded the second marking point. A small percentage of candidates suggested that the charge would decrease on the capacitor for a variety of reasons. This response was awarded zero marks.

7d HL

This question was left blank by a surprising number of candidates. The candidates who attempted this question generally did fairly well, although a small percentage switched the number of turns on the two sides and were awarded 2 marks for 12.9 V. A few candidates only calculated the RMS value of the input potential difference and were awarded one mark.

7e HL

A small number of candidates did not read the question and simply discussed how transformers work. Quite a few candidates connected the decrease in current with a decrease in energy lost to the power lines. Many candidates used the terms “step up transformer” and “step down transformer” without clearly indicated the connection to the potential difference. Given that some suggested that a “step up” transformer increases current, or even resistance, it is evident that these terms are too vague to be used in a proper exam answer. Likewise, others simply said that the voltage had been “stepped up” without clearly indicating that the voltage had been increased.

8a HL

Few candidates were awarded marks for this calculation. Many used the correct equation, but only for n=1 and stated that 13.6 was roughly 10. Quite a few used the energy to calculate a frequency, and then stated that the frequency was in the UV part of the spectrum. As a “show that” calculation, it was required for candidates to calculate the answer to one extra significant figure to be awarded MP2.

8b HL

This first part of this question was left blank by many candidates, but those who chose to attempt it did fairly well. The second part of the question was challenging with very few candidates received marks. Few candidates discussed this properly in terms of electrical potential energy choosing instead to discuss the stopping potential. Some discussed the kinetic energy of the charges, although in many responses the candidates discussed the impact of changing the voltage on the initial kinetic energy of the ejected electrons. A small number simply cited a version of the conservation of energy and made no attempt to connect it to the situation given. The final part of the question was not very well answered with many blank responses.

8c HL

For the first part of the question there were some incorrect diagrams drawn, but there were many that were close enough to be awarded marks. Candidates should be reminded to draw diagrams carefully - too many drew hasty slashes that were slightly angled or curved rather than using a ruler or some other straight edge to draw a clear, straight line. The second part of the question was left blank or barely attempted by many candidates - this is not surprising since it was the last question on the exam.

Recommendations and guidance for the teaching of future candidates

- Encourage candidates to learn the meanings of command words.
- Encourage candidates to read the examination questions carefully and to identify the number of physics points required to answer each question.
- When discussing energy changes, encourage candidates to include the correctly named type of energy and the place/object where the energy is stored.
- Encourage candidates to show clearly show their work so that examiners have the opportunity to award ECF marks if appropriate.
- Encourage candidates to take care when drawing and labelling diagrams.
- Give candidates practice with explaining concepts, and encourage use of proper terms, concepts, etc.
- When calculating a given value, candidates should write an unrounded answer with at least one extra significant figure.
- It is common on exam questions now to include a specified unit for the result. Candidates should pay attention to this an ensure that they are writing their response with the proper unit and power of 10.

Paper three

Component grade boundaries

HL

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-11	12-17	18-21	22-26	27-30	31-45

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0-3	4-7	8-10	11-14	15-18	19-22	23-35

General comments

The paper is designed in accordance with the Physics guide. Section A is prepared for summative assessment of core material, mainly of Topic 1 Measurement and uncertainties. The contexts for the assessment are selected appropriately, oscillations and internal resistance of a battery. One of the contexts required knowledge from core material.

Options in Section B are well balanced. Each of the options included questions measuring the level of knowledge, understanding, skills and other of the assessment objectives 1,2 and 3 required by the syllabus. In line with the Physics guide, the questions in each of the options presupposes knowledge on core material and AHL where appropriate.

Questions in section B used well selected contexts and applications. The candidates proved that they had enough time for the paper. Discrimination of the paper is at the appropriate level, the difficulty level of all the options is almost the same. Among answers we can see many examples of good understanding in each of the questions. Almost all candidates answered all questions from section A and all questions from one option selected.

The vast majority of candidates kept responses in the answer boxes provided and if used additional answer sheets they referred to this within the answer box. Handwriting seems to be at the same level as in the last sessions, the answers were legible, there was no problem with marking in black-and-white.

The areas of the programme and examination which appeared difficult for the candidates

The most difficult area in this paper was the application of physics knowledge to core material in questions focused on topic 1 Measurement and uncertainties. This syllabus specifies questions on Topic 1 will be set with the contexts of core material and it is critical that students carefully read the situation, and the stem of the question. The questions should be answered using their whole knowledge of core.

Main difficulties related to the syllabus:

- Explaining, how random and systematic errors can be reduced (1.2);
- Internal resistance (5.3);
- The Lorenz transformations, simultaneity (A.2)
- Relativistic mechanics (A.4);
- Principle of conservation of energy (2.3), solving problems using rotational quantities analogous to linear quantities (B.1);
- Energy changes in SHM (9.1)
- Generation of ultrasound in medical context (C.4)
- Describing rotation curves as evidence for dark matter (D.5)

The areas of the programme and examination in which candidates appeared well prepared

The well prepared candidates can analyse the situations, present working in a logical manner, and use proper terminology, physical quantities and units. They demonstrated understanding of facts and concepts and were able to use them with proper terminology. Also presented well developed competences to apply knowledge and abilities related to mathematics. Most candidates demonstrated the ability to clearly present well known facts in words and sentences. Amazing is, that in this paper well prepared candidates proved their ability to work throughout the range of very real to very abstract phenomena, applying both practical and theoretical physics.

The strengths and weaknesses of the candidates in the treatment of individual questions

Section A

1

Oscillating magnetized needle. Well discriminating question. The greatest difficulty was to carefully read the information, that the time on the graph is for 10 oscillations while in b i the question requested the time of 1 oscillation. Determining the units proved difficult for many, particularly in SL.

2

Internal resistance measurement. After the straightforward part a) part b) was more demanding, where candidates should know that in raising temperature of a metal its resistance also rises. Many answered in terms of energy loss, particularly in SL. This is a difficult question discriminating the best and average prepared candidates.

Section B, option A - Relativity

Answered by about 20% of the candidates. Increase in proportion of SL students answering this option this year, probably up to 20%.

3 HL, 3 SL

Metal wire and relativity. Well answered by average prepared candidates; in b ii many candidates forgot to mention the current caused by the moving positive charges.

4 HL, 4 SL

Muons. Well scored question for HL. SL struggled with using the correct method to calculate the times.

5 HL, 5 SL

Two rockets. Most candidates used spacetime diagrams well and used relativistic velocity addition, but the majority of candidates failed to explain simultaneity in c).

6 HL

Pion decay. Many candidates proved they had well mastered the concept of conservation of momentum and working with appropriate units in relativistic mechanics, but there is a difficulty in solving complex problems in collisions.

7 HL

Beam of light on a surface of a planet. Well done by many candidates.

Section B, option B - Engineering physics

answered by about 30% of the candidates.

8 HL, 6 SL

Merry-go-round. Good discrimination on question. Part a) was done very well, but the work done by the child was only well calculated by the best prepared candidates.

9 HL, 7 SL

Heat engine. For HL, most prepared candidates answered all sub-questions well, but some candidates in b ii assumed an isothermal process and failed this subquestion. For SL, the calculations were generally well-answered, but the more descriptive answers demonstrated a lack of conceptual understanding.

10 HL

Outlet pipe. The candidates proved knowledgeable in laminar and turbulent water flow and demonstrated the ability to apply it. Weaker candidates did not show the steps of derivation in b) clearly enough.

11 HL

Spring-mass system. Majority of candidates correctly identified the damped vibration, but only the best candidates were able to use the formula from AHL physics to calculate the value of Q.

Section B, option C - Imaging

answered by about 10% of the candidates.

12 HL, 8 SL

Lenses. Majority of candidates well answered part a). In part b), the image obtained by Lens 1 was constructed by the majority of candidates but only the best candidates were able to use this image as an virtual object for lens 2. The best candidates proved their ability to use ray diagrams in such complex situations. Some candidates also calculated the value of focal length to get a more precise value. in a) i)

13 HL, 9 SL

Signal in an optic fibre. Well done question. A number of students, especially in SL, failed to make the attenuation negative, resulting in a signal stronger than the original. Again students should consider if their answer is possible. Weaker candidates demonstrated difficulty in explaining the improvement of optic system using graded-index fibre in c) iii).

14 HL

Well answered question, except for generation of ultrasound in medical context. Only a few the best candidates have knowledge in this area, explicitly formulated in the syllabus.

Section B, option D - Astrophysics

answered by about 35% of the candidates.

15 HL, 10 SL

Solar system. The basic terminology of objects in astrophysics is well mastered by majority of candidate answering this option, but many candidates described comets as objects freely moving through the universe, without gravitational attraction.

16 HL, 11 SL

A main sequence star. Well answered except for part a1. The students did not read the stem and consider the data shown, incorrectly believing the hydrogen emission spectrum came from the star. The alternative common mistake was that the absorption spectrum lines are there because of nuclear synthesis, because of ‘missing’ hydrogen. In b ii) many candidates did not realise, that there is a difference between the temperature of the Sun and the star.

17 HL, 12 SL

Age of the universe. Well answered, but many candidates had difficulty in POT, failing to note the units of the Hubble constant.

18 HL

Supernova. Well answered by average candidates.

19 HL

Average candidates had problems in the explanation required in c). This subquestion discriminated well between the best and average prepared candidates.

Recommendations and guidance for the teaching of future candidates

- Students should always check that the calculated answer is reasonable.
- Practice in explanations, using Physics language eg proportional rather than ‘as one goes up so does the other’, using energy, force, pressure, power, correctly and precisely.
- Questions requiring ‘show’ should be laid out carefully, showing steps and reasoning.

- Candidates need to be familiar with the Data Booklet, with the units used in each formula, and the proper use of each.
- Work that is crossed out is not marked, even if it can be seen to be correct. So don't cross out an answer until the reworked answer is finished.
- Students need to practice interpreting a question to decide what is required. This can be achieved by issuing questions that do not need to be answered, but only need to be used to determine what is required. Once that is determined, then they could answer the question, as a separate exercise. Very few papers showed any evidence of analysis of the question, by highlighting or underlining significant terms in the instructions eg show, deduce, calculate, using, explain.
- Definitions are at the very heart of Physics – they must be known and practiced
- Round off at the end of a string of calculations, not at each step.
- As this is a Physics examination: explain the physics involved rather than generalised statements.
- The practice of removing constants from equations before substituting values when a ratio is required would simplify working and reduce arithmetical errors eg 11/16 bii.