November 2017 subject reports

Physics

Overall grade boundaries

HL

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 25	26 - 37	38 - 46	47 - 55	56 - 64	65 - 100

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 23	24 - 33	34 - 43	44 - 53	54 - 63	64 - 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

A wide range of work was submitted, from traditional mechanics labs (e.g. how mass affects the period of a spring oscillator) to sophisticated online database investigations (e.g. exoplanets). There were a few computer simulations investigations too (e.g. properties of a Trebuchet). Some investigations were very popular, including the formation of craters, frequency and musical string length, refractive index and solution density, wave speed and water depth, the coefficient of restitution of a bouncing ball, and of course projectiles, with and without air friction. How temperature affects various properties was a common and interesting theme.

What makes a good investigation is not the topic or research question as such but it is rather the depth of understanding demonstrated by the student and a well-focused research question or task on a scientifically interesting topic.

Mechanics, waves, and electricity and magnetism were popular topics. Most work submitted was suitable for assessment. With very standard investigations students often made a hypothesis that was obvious and already known in the given theory. Occasionally students would include two or three related investigations in one lab report. As a result investigations lacked the depth of analysis needed to earn high marks. A single focused research question is the best approach. A few investigations could have been extended essays.

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 interest would not be related to specific research questions. For example, a love of music is not related to an investigation into the speed of sound. Teachers need to encourage students to demonstrate their curiosity and insight in the investigation itself, in the research question, in the details of methodology and analysis, and in other contributions made by the student to their individual investigation. Teachers often overmarked PE thinking that an interest in the general topic was enough to earn full marks. Because PE is assessed in a holistic way, students should not add a sub-title section "Personal Engagement."

Exploration strengths

There were many interesting and challenging investigations. These always included a single and well-defined independent variable and a quantifiable dependent variable. Appropriate investigations always 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 water wave speed and water depth, water surface tension and temperature, air pressure and frequency of a trumpet, radius of a pipe and end correction for sound, properties of a wire cutting ice, and temperature and available power of a battery. There were also several successful investigations on the nature of large amplitude pendulums. 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 some 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 the investigation. 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. Historical background is not relevant. Students need to explain their methodology, assumptions as well as the scope and limit of their investigation, but they do not need to give 28 steps of their method. Often students include photographs when a clear sketch would have been better.

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. Most students demonstrated the ability to obtain and record data, including uncertainties in raw data. 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 some graphs were too small to appreciate or too much information was 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 27.83%? 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. The 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 could ask students to understand what they are saying.

Evaluation strengths

The evaluation criterion remains one of the most demanding criteria. 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. 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 should 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 restating 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 make general and qualitative comments only. 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. In an evaluation students need to appreciate the physical meaning of the quantities under investigation, and so they need to interpret the data correctly. Some students failed to appreciate the physical quantities under study and so they failed to appreciate what they have established. There is more to a graph than a simple equation. Some evaluations were superficial, blaming human error or friction, or systematic error.

Communication 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 content, 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 the temperature of a metal spring affects the spring constant” and not titles like “Investigating Collisions” or “Momentum.” The majority of reports used correct and relevant scientific notation, equations and units. Students are expected to present equations properly. The majority of reports were within the 12-page expectation. It is clear ten pages is a perfectly reasonable length for a focused and concise IA report. Reasonable margins, spacing, appropriate scales of graphs and data tables, all help the communications criterion. Most students consistently and appropriately provide references to their work (in a variety of consistent and acceptable ways). Academic research is expected. Research questions and hypothesis need to be supported by relevant scientific information, relevant to the investigation and not historical background.

Communications weaknesses

Some 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 suggests a lack of focus.

The moderator needs to know how the student performed 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 to provide guidance during the entire IA investigation process. Some of the weaknesses that could have corrected during the student's design stage include multiple independent variables, unquantifiable variables, multiple investigations, and unrealistic experimental expectations.
- Students need to acknowledge and appreciate the physics that is already known about their research question. Too often students make up common sense physics, or fail to appreciate well-known theories.
- Encourage students to include a descriptive title to their report and make sure the research question is identified and explained within the first paragraph.
- 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.
- When reading the student's report draft, ask students to justify the line fit of any scatter data (and not to assume a linear fit), to include appropriate quantities and units with data and graphs, and to make sure the evaluation relates to the research question and data.
- It is important that students have a sound knowledge of the assessment criteria. By discussing extensions to class investigations or ideas relating to topics studied throughout the course when a student is expected to come up with their own research

topic they can imagine exciting possibilities.

Further comments

- The internal assessment aspect of the physics curriculum is working well. Students are involved, taking the initiative and responding to the challenge of an individual investigation.
- 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.
- 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. Comments can also be added throughout the report or, preferably, at the end of the report. It is best to not just copy the official five pages of IA criteria and checkmark the assessed levels.
- 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.

Paper one

Component grade boundaries

HL

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 14	15 - 17	18 - 19	20 - 22	23 - 25	26 - 40

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 12	13 - 14	15 - 17	18 - 19	20 - 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.

Only a small percentage of the total number of teachers or the total number of centres taking the examination returned G2's. For SL, there were 27 responses from 251 centres and for HL there were 22 responses from 326 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 question writing.

The HL (SL in brackets) paper was regarded as being of appropriate difficulty by about 91% (88%) of the respondents with 5% (12%) finding it too difficult. The papers were deemed to be of a similar level of difficulty as the previous year's paper by 73% (50%) of respondents, although it should be noted that the SL paper was considered more difficult than the previous years by 46%. The clarity of wording also showed some differences between the SL and HL paper, with 82% of HL respondents feeling that the paper was deemed to have good or better 'clarity of wording' while only 66% of respondents reported the same level. Over 86% (85%) of teachers judged the presentation to be good, or better.

There was also a feeling expressed in the G2 comments that the wording of some of the questions was somewhat inaccessible for second language learners.

It must be stressed that this very positive feedback was from only about 10% of the schools so it must be regarded with some caution. But, from the evidence gained from the G2 comments, the examiners were satisfied that the papers met with general approval.

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 examiners intention to ‘trick’ students. But students cannot expect multiple choice questions to follow a familiar pattern. They should read the 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 dimensions of the responses rather than a detailed working of the algebra.

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

Statistical analysis

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.

HL P1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	135	75	1417	38	3	84.95	0.30
2	64	1261	217	119	7	75.60	0.25
3	407	71	121	1068	1	64.03	0.31
4	385	261	872	140	10	52.28	0.47
5	148	174	118	1222	6	73.26	0.40
6	629	638	356	30	15	38.25	0.00
7	939	62	605	58	4	56.29	0.52
8	90	878	513	165	22	52.64	0.55
9	37	477	42	1108	4	28.60	0.03
10	32	1498	112	24	2	89.81	0.21
11	65	1487	43	69	4	89.15	0.21
12	193	52	732	682	9	40.89	0.69
13	895	323	153	286	11	73.02	0.39
14	552	397	626	88	5	33.09	0.41
15	739	259	317	347	6	44.30	0.60
16	399	736	261	257	15	44.12	0.52
17	841	231	384	201	11	50.42	0.36
18	203	550	780	134	1	32.97	0.30
19	259	660	526	208	15	39.57	0.53
20	86	302	241	1032	7	61.87	0.54
21	118	692	338	516	4	41.49	0.30
22	116	188	1077	276	11	64.57	0.26
23	281	194	166	1016	11	60.91	0.28
24	16	50	1372	228	2	82.25	0.16
25	175	1179	122	181	11	70.68	0.42
26	570	179	502	402	15	34.17	0.35
27	99	271	1230	57	11	16.25	0.06
28	784	334	293	246	11	64.57	0.35
29	646	417	193	392	20	38.73	0.40
30	1077	374	139	69	9	64.57	0.48
31	267	271	828	276	26	49.64	0.62
32	112	209	1176	157	14	70.50	0.53
33	112	698	303	539	16	41.85	0.22
34	99	109	970	477	13	28.60	0.31
35	244	414	896	81	33	53.72	0.58
36	117	1010	156	361	24	60.55	0.47
37	159	1007	250	243	9	60.37	0.57
38	520	539	262	324	23	32.31	0.52
39	470	487	507	183	21	30.40	0.25
40	219	922	291	216	20	55.28	0.33

SL P1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	137	1130	326	72	3	67.75	0.33
2	139	101	1261	153	14	75.60	0.40
3	866	605	143	48	6	51.92	0.63
4	343	631	376	309	9	37.83	0.50
5	367	91	163	1039	8	62.29	0.22
6	486	423	624	122	13	37.41	0.44
7	463	747	415	35	8	44.78	-0.15
8	864	202	181	410	11	51.80	0.39
9	66	1329	195	74	4	79.68	0.31
10	76	631	647	281	33	37.83	0.43
11	307	318	646	386	11	38.73	0.33
12	88	336	670	563	11	33.75	0.55
13	110	744	588	210	16	35.25	0.46
14	97	113	193	1257	8	75.36	0.42
15	667	405	148	436	12	64.27	0.46
16	150	403	828	268	19	49.64	0.06
17	291	311	840	197	29	50.36	0.48
18	502	458	296	392	20	27.46	0.41
19	488	933	161	65	21	55.94	0.54
20	702	388	379	180	19	42.09	0.34
21	158	523	281	689	17	31.35	0.21
22	389	440	431	384	24	26.38	0.21
23	143	397	364	729	35	43.71	0.46
24	145	525	387	582	29	31.47	0.18
25	146	234	966	284	38	57.91	0.17
26	36	89	1325	196	22	79.44	0.24
27	233	328	878	203	26	52.64	0.33
28	325	969	149	188	37	58.09	0.44
29	387	251	576	420	34	23.20	0.25
30	85	1092	310	155	26	65.47	0.32

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 28% in HL and 23% in SL (relatively 'difficult' questions) to about 90% in HL and 80% in SL (relatively 'easy' questions). The papers gave an adequate 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 November.

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.

The majority of questions had a positive value for the discrimination index (only SL 7 had a negative index). Ideally, the index should be greater than about 0.2. Four HL and four SL questions fell below this standard. However, a low discrimination index may not 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 several blank responses throughout the test with a slight increase towards the end as in previous years. This may indicate that some candidates had insufficient time to complete their responses, while others left 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, some of the 'distractors' should be capable of elimination, thus increasing the probability of selecting the correct response. If candidates concentrate on selecting the correct response – instead of working out the correct answer (as they might in paper 2) then there should be adequate time to complete all the questions and check the doubtful ones.

SL and HL common questions

SL 6 and HL 4

Candidates struggled with this question. Incorrect responses were evenly divided amongst A and B, which may indicate that the candidates were guessing rather than taking the time to work out the inclined plane problem. This is a good example of a question that can be answered by mentally changing the angle – reducing the angle to zero or increasing the angle to 90 degrees. Only the tangent of the angle gives a result that makes sense physically.

SL 7 and HL 6

This was an interesting question – this question was correctly answered by a large number of candidates, but it also had a very low (negative for SL) discrimination index meaning that it was answered incorrectly more often by stronger candidates. The most commonly chosen incorrect answer was A, which indicates that stronger candidates may have believed this was a conservation of energy question. It is worth taking the time to introduce candidates to multiple spring problems.

SL 10 and HL 8

The most commonly chosen incorrect answer was C, which is the average power transferred to the liquid. These candidates did not subtract this from the input power to determine power lost. It should be noted that this question was left blank by 22 candidates – a surprisingly high number for this early in the exam. Perhaps candidates were put off by the necessity to do calculations by hand. It is worth having students put their calculators away on occasion throughout the course to give them experience with calculations.

SL 15 and HL 13

Unfortunately, the fractions for answers A and B were equivalent. We accepted both answers for this question.

SL 18 and HL 16

This should have been a straightforward question, but the candidate responses were spread among all the options indicating quite a bit of guessing. Given that the loop was within the circuit the candidates should have recognized that the potential difference was zero. Since the potential differences for each resistor had to combine to be equal to zero, B is the only clearly correct answer. This is an excellent example of a question where a candidate should pause and think about the question and look carefully at the given answers to see which makes sense.

SL 20 and HL 17

This was a challenging question as candidates needed to recognize the need to apply a “hand rule” correctly to determine the force acting on Q. C was a commonly chosen incorrect answer, which may indicate that many of these candidates recognized the basics of the question, but simply applied the wrong rule.

SL 22 and HL 19

This turned out to be one of the more challenging questions. Candidates should have recognized that mass does not affect orbital speed, and therefore does not affect orbital period.

SL 24 and HL 21

While this question did not specifically mention the fusion of lighter elements, it can be reasonably assumed that this is the reaction the question is referring to, making B the only correct answer. D received the bulk of the incorrect answers, which cannot be correct regardless of how the question is read. This concept of nuclear binding energy can be difficult for students to understand and many take the name very literally – that this is they think it is the (input) energy necessary to bind together the nucleus. This question is a good example of how fundamental understanding of a specific concept can impact a candidate's choice of response.

SL 25 and HL 22

It is worth noting that the time axis was vertical in this question, not horizontal. Students should be given exposure to both types of Feynman diagrams. The guide does not specifically limit Feynman diagrams to horizontal time axis diagrams only.

SL 29 and HL 26

This question was quite challenging for candidates. It is possible that many did not know what the solar constant represents. Option III does not affect the amount of sunlight reaching the Earth as a whole and therefore should have immediately removed all other answers from consideration.

SL 30 and HL 2

There was concern expressed in the G2 comments that this type of meter is not commonly used in schools anymore. However, this question was well answered by the majority of candidates. HL only questions

Q 5

This question was well answered, although there is some concern about candidate's having to compare the lengths of the arrows. It is worth noting that candidates can use a ruler in paper one.

Q 9

This was a very difficult question for the candidates with very few choosing the correct answer of B. The most selected answer was D, which was the opposite order. It is possible that candidates did not understand the proportion portion of the question and answered the question based solely on internal energy.

Q 12

The most selected answer by candidates was C, which is the proportion of the light passing through the second filter compared to the light passing through the first. However, it appears that most candidates missed that the first filter decreases I_0 by ½ making D the correct response.

Q 18

It seems that many candidates applied the right-hand rule, but did not account for the fact that the question is about electron flow and not conventional current. This is one of those key phrases that candidates need to pay close attention to when reading the question.

Q 27

This question was poorly answered with the majority of candidates getting C for the answer. The additional relationship between mass and omega ($\omega^2 \propto m^{-1}$) was missed by candidates. Since the increase in mass does not affect the total energy of the system only the increase in amplitude changes the energy.

Q 28

This question was intended to compare the interference patterns formed by a pair of slits and a single slit. After discussion in standardization, and consideration of G2 comments, we accepted A and C as correct answers due to a possible interpretation of the term “outer maxima” and the fact that fewer maxima will be observed as well.

Q 33

The fact that D was the most chosen incorrect answer seems to indicate that candidates were confused about the difference between the electric field inside a metal sphere (which is zero) and the potential inside a metal sphere (which is not zero).

Q 34

It appears that many candidates did not realize that the coil is only making ½ a rotation during time t. Therefore, the induced emf is twice what it would be if the coil made one full rotation in time t, making D the correct response. This is another good example of a question that candidate’s need to read closely and think about before applying a data booklet equation.

Q 38

Increasing both the resistance and the capacitance increases the time constant for a circuit. This therefore extends the time it takes for the capacitor to discharge to half its initial value which makes B the correct response. It appears that many candidates thought the changes would offset each other which is why so many chose A.

Q 39

The responses to this question were almost randomly distributed. The KE of released photoelectrons varies, which eliminates A and B as possible answers. D is incorrect due to work function being the <u>minimum</u> energy required to release a photoelectron from the metal's surface, leaving C as the only possible correct response.

SL only questions

Q 3

This question was answered correctly by roughly half the candidates with a significant number choosing B indicating that these candidates confused the area under the graph with the gradient.

Q 4

Only a third of candidates answered this correctly. The other three answers were almost all equally chosen, which implies that the candidates were probably guessing. It is interesting that this question used area of a velocity-time graph to find displacement and the previous question showed many candidates thought the area under a displacement time graph was velocity. These two questions taken together indicate that many candidates are struggling with the interpretation of area on kinematics graphs.

Q 8

This was a straightforward question involving an explosion with roughly half of the candidates correctly choosing A. It is worth noting that D was the most common incorrect answer indicating that these candidates believed that momentum increased in the explosion. It is worth taking the time to highlight the effects of internal forces on the overall momentum of a system during instruction.

Q 21

The tangential velocity of a mass moving in a vertical circle will decrease as the mass is moving towards the top of the circle, which will cause the kinetic energy of the mass to decrease. However, the term “constant period” may have caused confusion for some candidates who possibly interpreted this to mean that the mass was moving at a constant velocity which may be why so many chose D as their response.

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 session.

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 also can 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, estimation, 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 lead 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!

This guide does invite the candidates to recall certain simple facts, although most of physics is process orientated. 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 - 9	10 - 19	20 - 28	29 - 37	38 - 47	48 - 56	57 - 95

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 13	14 - 18	19 - 23	24 - 28	29 - 50

General comments

Candidates were able to show strengths in all areas of the syllabus tested by this examination. An area which did cause concern was single slit diffraction and diffraction gratings as there was evidence from blank responses to question 6 that this section caused candidates significant difficulty.

Again, it was good to see the continued improvement in the way candidates laid out their responses to numerical calculations and improved knowledge of relevant units.

Knowledge of key terms in physics remains an issue and even though there is less emphasis on learning definitions students must be able to use the vocabulary of physics effectively.

There were 2 typographical errors in this paper both of which examiners were aware of before marking started. These will be corrected in the published version of the paper.

The first in 1ei) where candidates were asked to show that the acceleration of a sledge was 2 ms^{-1} where in fact it should have been quoted as – 2 $m\ s^{-2}$.

The second in 3ai) where the diagram showed a W^- boson which should be a W^+ boson.

Examiners sent any responses showing possible candidate confusion to the Principal Examiner for each paper who applied compensatory marks.

Data on the attempt rate of individual questions indicates the errors had no effect on candidates attempting the relevant questions.

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

At HL

- Interpretation of situations involving electromagnetic induction
- Precise descriptions of energy changes in SHM

- Details of high energy scattering experiments
- Single slit diffraction
- Diffraction gratings
- Contextual description of the enhanced greenhouse effect

At SL

- Calculation of orbital periods
- Construction of a potential divider circuit
- Contextual description of the enhanced greenhouse effect

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

At HL

- Free body force diagrams
- Calculations in the mechanics section
- Newton's second law of motion it terms of momentum
- SHM calculations and use of units
- Refractive indices and total internal reflection
- Thermal physics calculations
- Descriptions of the molecular structure of solids and liquids

At SL

- Thermal physics calculations
- Descriptions of the molecular structure of solids and liquids
- Free body force diagrams
- Refractive indices and total internal reflection
- Descriptions of the molecular structure of solids and liquids

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

SL and HL 1a

This was generally answered well by candidates with forces shown by arrows attached to the object and correctly labelled. Some candidates omitted the friction force and some added an extra 'driving force' down the slope. It was good to see that many candidates, acting on previous advice, used a ruler for their arrows.

SL and HL 1b

This question required the origin of each of the forces that needed to be in equilibrium and this was often missed, particularly the Earth in relation to the gravitational force. A significant number of candidates restated the stem of the question regarding the forces being in equilibrium rather than discussing what this meant. Consequently, this proved to be a quite low scoring question. Many candidates at standard level misapplied Newton's Third Law to explain why the forces must be in equilibrium.

SL and HL 1c

This was generally very well done at both the standard and higher level with candidates laying out calculations well. A minority attempted to tackle this question based on energy conservation, an approach which did not score any marks.

SL and HL 1d

Many candidates recognised that the snow would extend the time for the collision and examiners were pleased to see that this was usually related to a smaller force on the girl by applying correct physics. The point often missed was that the change in momentum would be the same for both snow and ice. It was expected that this point would be explicitly made as the question attracted one more mark than is usual. Answers referring to snow being safer as it is less slippery were not awarded any marks.

SL and HL 1ei

This was generally well answered at the higher level, again with candidates structuring their answers well. Candidates at the standard level struggled a bit more with the vector nature of this calculation. Sometimes the component of the weight down the slope was omitted which led to an answer which did not round to the show that value. If this is the case students should be encouraged to review their solution. The use of g = 10 ms^{-2} was allowed here but the use of 9.81 ms^{-2} as given in the data booklet is preferred.

SL and HL 1eii

As with the previous part this was answered well. Many SL candidates who struggled to calculate the acceleration in the previous part were still successful in calculating the distance.

SL and HL 1f

The first part of the solution, calculating the maximum value of static friction was generally well done and many were then able to go on to compare this to the component of the weight down the slope to come to a conclusion. Some candidates, however, incorrectly compared this to a value for dynamic friction to reach a conclusion.

HL 2a

The vast majority were successful with this calculation.

HL 2bi

In this part of the question too many candidates answered that the orbit/orbital speed is different rather than saying whether it was higher or lower.

HL 2bii

It was common for candidates to appreciate that a propulsion system would be required for Y to remain stationary with X, but many didn't add to this to score a second marking point. It is worth stressing to students that they should always be aware of the number of marks available for each question part. Incorrect answers to this often referred to Y being closer to Earth and experiencing a greater force of attraction which would send it crashing back to Earth without the propulsion system.

HL 2c

Examiners were looking to award marks based on an answer referring to electrons or an answer referring to conventional current. There was a reasonably even split as to how candidates answered this and successfully scored at least 2 of the marks. Candidates who simply stated laws of electromagnetic induction without relating them to the situation in the question did not earn any credit.

HL 2d

This proved to be a challenging question part asking about a complicated situation. It was answered well by some candidates but caused a good deal of confusion with others. Many were, however, able to gain some credit for a discussion involving a complete/incomplete circuit.

HL 2e

A straightforward calculation answered well by many.

HL 2fi

This too was answered well by the majority of candidates who exhibited sound algebraic skills. It was particularly pleasing to see that very many candidates were able to assign a correct unit to their final answer.

HL 2fii

This part of the question was often answered poorly. It should have been straightforward asking only for a discussion of elastic potential energy stored in the cable being converted to kinetic energy of the satellite and then how any times this happened in a cycle. Many candidates only talked vaguely about PE being converted to KE but made no mention of particular parts of the system. It is worth stressing to students that when energy changes are described they should state the type of energy and the 'place/object' that has the energy. Also, candidates didn't make accurate comments about how many times the changes took place in a cycle.

SL 2ai and HL 3ai

For higher level many candidates could correctly consider conservation of lepton number and charge to deduce the nature of the particle. On the standard level paper candidates did not need to identify the particle, but did need to identify why an electron neutrino was the correct particle. Many candidates discussed the conservation laws, but few specifically cited that the lepton number would need to be +1. Many candidates did recognize that the charge would have to be zero, and almost none discussed the baryon numbers.

SL 2aii and HL 3aii

The majority were correctly able to identify that hadrons are comprised of quarks and/or that leptons are fundamental. Fewer discussed which type of particle experienced which force.

HL 3bi

In this part of the question examiners were looking to award credit for practical details of the experiments. This was indicated in the question by ‘how these experiments are carried out’. Many candidates didn’t provide these details but instead talked about general principles or results of the experiments.

HL 3bii

The mark scheme was prepared to credit answers for three alternative approaches. The overwhelming number of answers were based on alternative three. Those candidates that answered using either of the first or second alternatives almost always scored full marks while alternative three produced more mixed results. There was a good deal of confusion shown by candidates between the effects of the coulomb repulsion force and the strong nuclear force as the high energy particles approached the nucleus.

HL 3c

Examiners were impressed by the wide range of analogies encountered here ranging from water flow and electric current to the very popular plum pudding model of the atom. Some candidates were unaware of the meaning of analogy and continued the discussion of high energy particle experiments.

HL 3di

This was generally correctly answered by using either the information given in the question or, more commonly, the Fermi radius given in the data booklet.

HL 3dii

This was almost always correctly done. It is worth noting that if the candidates answer to the previous part does not lie within the grid given then they have made a mistake and should be aware of this.

HL 3diii

Again this was very well done with most candidates drawing the required line. The most common incorrect answer was a straight line joining the 2 points.

SL 3ai and HL 4ai

This calculation was answered well by most candidates.

SL 3aii and HL 4aii

Very few candidates scored both marks for this as the majority neglected to calculate the area or did so incorrectly.

SL 3aiii and HL 4aiii

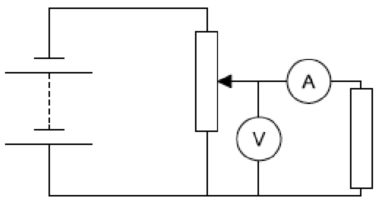
Many candidates discussed the use of the resistivity formula and said that it was useful to be able to calculate resistance, area or length for a particular application. Credit was awarded for more general answers involving intrinsic properties of materials or choice of a particular material for a particular application.

SL 3b and HL 4b

At the higher level this was very well answered with many candidates including the change in both length and area for their justification as to why the resistance decreased. At the standard level, many candidates recognized that the resistance decreased but rarely recognized that both the area and length had changed.

SL only 3c

This question was generally poorly answered. This was left blank by many candidates. Those who drew circuits often did not include the carbon film resistor which resulted in no marks being awarded. For those who did include the resistor some were able to correctly connect the ammeter and voltmeter, but very few drew circuits that used a potentiometer correctly. A correct circuit is included below for review.



SL 4ai and HL 5ai

Another straightforward calculation tackled well by the majority of candidates.

SL 4aii and HL 5aii

It was common for candidates to be able to identify that the light hit the face at an angle of 57° so scoring the first marking point. It was slightly more common to see answers based on a calculation of the critical angle although many did appreciate that as the sine of the refracted angle is 1.1 then the angle did not exist. Many candidates produced well laid out arguments for both alternatives given.

SL 4aiii and HL 5aiii

The majority showed total internal reflection on the diagram but then often stopped the ray at the next face rather than showing it emerging.

SL 4bi and HL 5bi

This was answered very well with many candidates scoring 3 or 4 marks. The main error made by candidates was to subtract the two energy values calculated in the first 3 steps rather than add them.

SL 4bii and HL 5bii

Almost all candidates scored the mark here for an appropriate difference.

HL 6

Overall the most number of ‘no responses’ was seen in this part of the paper.

HL 6ai

Surprisingly few candidates commented on the fact that this pattern is a result of single slit and double slit patterns combined. Most, however, recognised that the zero intensity at A was a result of destructive interference or discussed suitable path or phase differences.

HL 6aii

Candidates often used the double slit formula here, calculating a slit separation value rather than the slit width asked for. This approach scored zero. The small angle approximation for sin or tan was allowed in this instance.

HL 6aiii

The most common number of fringes identified was 3.5 enabling candidates to score 1 error carried forward mark. It was relatively rare to see 3 fringes correctly identified. If candidates made no attempt to include the number of fringes they were still able to score an ECF mark for using the correct formula.

HL 6bi

In this question part candidates scored 1 mark for recognising a difference between the 2 patterns, a second mark for explaining this difference in terms of slit width, number of slits etc. and a third mark for a further difference and explanation. Commonly examiners saw differences listed without appropriate explanations.

HL 6bii

This calculation wasn't well attempted by candidates. Many recognised the correct formula to be used but were only able to calculate $\Delta\lambda$ and weren't aware of the significance of m or N.

SL only 5a

Candidates struggled a bit with this calculation, with many calculating orbital periods that did not make sense physically.

SL 5bi and HL 7ai

This was correctly calculated by almost all candidates.

SL 5bii and HL 7aii

A significant number of candidates thought that what was important in answering this question was the magnitude of the difference between the 2 peak wavelengths. As a result, examiners saw many answers referring to the amount of energy absorbed by the Sun compared to the amount of energy absorbed by the Earth. There were confusions about radiation being reflected from the Earth and absorbed by the atmosphere and radiation reflected by the atmosphere and absorbed by the Earth.

SL 5c and HL 7b

Examiners were looking for answers that gave the sense of widespread scrutiny of scientific work and terms such as peer review and international conferences were often seen in the answers. A significant number of candidates restricted their answers to evidence for global warming.

HL 8a

This was well answered with the most common mistake being confusion of electric field strength with electric potential.

HL 8b

This was often correctly answered, but ECF was awarded in the next part of the question for whatever direction was indicated here.

HL 8c

Most candidate could discuss the proton and electron moving in opposite directions. There were many attempts to describe the relative sizes of the forces and accelerations of the particles but many missed the fact that the comparison is only valid initially or when they are at X. The changes in strength of the field were less commonly discussed.

Recommendations and guidance for the teaching of future candidates

- Encourage candidates to learn the meanings of command terms
- 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 type of energy and the ‘place/object’ where the energy is stored
- When discussing changes in a physical situation it is important that candidates use terms such as higher/lower rather than changed/different
- Encourage candidates to show their working so that examiners have the opportunity to award ECF marks if the mark scheme allows
- Encourage candidates to take care when drawing and labelling diagrams

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 - 24	25 - 28	29 - 45

SL

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 8	9 - 11	12 - 15	16 - 18	19 - 22	23 - 35

General comments

The paper matched the physics guide requirements. Section A covered topic 1: measurement and uncertainties. Contexts of water heating, internal resistance of an electric cell and fall of a metal ball were presented and the vast majority of candidates understood the context of the investigations.

Options in section B were well balanced. Each option measured the level of the knowledge, understanding, skills required by the guide. The paper presupposed knowledge of the core material. The candidates had enough time to complete the paper. Discrimination of the paper was appropriate. Among answers, we saw many examples of high level understanding. 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 extension sheets were used, they referred to this in the answer boxes. Handwriting seems to be at the same level as in the previous sessions and the answers were legible.

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

This paper was well balanced, so some candidates failed at some of the more demanding and challenging sub questions. Such sub questions required presenting work in a logical and clear manner with well-focused answers to questions instead of only general ideas. Use of scientific notation (mathematical requirement) helped to avoid power of ten (POT) mistakes. Some candidates often failed in these aspects. Many weaker candidates failed in knowledge of the history of physics, where the guide requires such knowledge. Generally, command terms as define, show that, calculate, suggest, identify, determine, deduce, outline were appropriately followed by the candidates.

Difficulties related to the syllabus details:

- Number of significant figures appropriate in an answer with expressed uncertainty (1.1 and 1.2)
- Gradient and intercepts (1.2 and mathematical requirements)

- Simultaneity of two events in two different reference frames (A.2)
- Representing time dilatation and length contraction on spacetime diagrams (A.3)
- Solving problems involving rolling (B.1)
- Solving problems involving static and dynamic (solid) friction (2.2)
- Free-body diagrams involving buoyancy (2.2 and B.3)
- Solving problems involving converging mirrors and angular magnification of simple optical astronomical telescopes (C.1 and C.2)
- Step-index fibres and dispersion (C.3)
- Critical density (D.5)

Other difficulties:

- Power of ten (POT) mistakes in calculations, ignoring prefixes (metric multipliers) in units as kilometer, kilojoule
- Layout of working in numerical questions, poorly presented answers leading to a wrong answer makes it hard to see where the mistake occurred and then award partial or ECF marks
- Sequencing the presentation of facts to support an explanation and description
- Quite often candidates read questions superficially and, even if they responded, they did not answer the question, e.g. in the questions 6(d), 9(e), 15(b)

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

A great majority of candidates have clearly used the physics guide during their study and final revision.

The more able candidates had enough knowledge and were able to apply it to new situations, were able to analyze situations, present working in a logical manner and use proper terminology, physical quantities and units. The majority of candidates showed an ability to analyze situations in various contexts, to read and understand questions. They demonstrated the understanding of facts and concepts and were able to use them with proper terminology. Most candidates demonstrated an ability to clearly present well-known facts in words and sentences.

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

Section A

All three questions were accessible to more able candidates. However, some candidates struggled in different parts of different questions.

1a

Water heating. The vast majority candidates drew the best fit line correctly, but a considerable number of candidates joined the data by a straight line. So, the term “best fit line” is still not understood by a significant portion of candidates.

1b

More than half of the candidates drew a tangent correctly, most of them used two points separated enough to obtain the gradient and then calculated the value of this gradient. Only a few candidates divided the value for 80°C by this temperature. A common mistake was conversion to kelvin. The unit for the gradient was often correctly presented.

1c

Surprisingly significant numbers of candidates were unable to complete a calculation of the energy. A common mistake was incorrect use of metric multipliers, often resulting in a power of ten mistake. In answers to the next part of this question lot of correct answers can be found. There were a number of candidates that propagated the significant figures using the mathematical method and did not propagate the uncertainty.

2

Internal resistance (a and b) In this question examiners looked for the value of the gradient. The majority of candidates used the formula for electromotive force, but many were unable to make algebraic manipulations clearly presenting the gradient of the linear graph. Only the better candidates found the value of the intercept.

3

Freefall measurement (a and b) Most of the candidates demonstrated that they are able to apply the concept of precision and accuracy.

Option A

Relativity

4

Maxwell’s work. Most candidates mentioned light and its propagation.

5

Two rockets and an observer on Earth (a) Most of the candidates are familiar with the term frame of reference.

5b

Only the more able candidates were able to use the closing speed and the time for the observer on Earth.

5c,d and e

Velocity addition is generally well understood, but part (c) was quite surprisingly not well answered. Only some candidates expressed the meaning of the velocities in the formula, even when they were able to use them appropriately.

6

Spacetime diagram for a train in a tunnel (a) Proper length is a well-known concept for many candidates.

6b

Most candidates are familiar with spacetime diagrams. Only the best candidates could use it in this situation.6(c and d) Length contraction was well understood in this situation by the majority of candidates. Simultaneity of two events in two different reference frames was too difficult for most of the candidates. Almost no candidates used the spacetime diagram for explaining the paradox.

7 HL only

A decay of a particle. Some better candidates were able to determine the rest mass of the particle, but the initial speed was determined only by the best candidates. Many mistakes in algebraic manipulation were made by the candidates, like the omission of square or square root.

8 HL only

Tics of a clock near a black hole and gravitational time dilatation is well understood by most of the more able candidates.

Option B

Engineering physics

9 and SL 7

A rolling hoop (a) Free body diagrams for an object on an incline are well understood by most candidates. Only a few candidates drew non-existent forces. Some candidates drew the normal force vertical and some candidates did not mention it. Ignoring the point of application was a quite common mistake.

9b and c

This question with a rolling object proved difficult. Most candidates solved this problem as a translational motion of a point mass. Most of the candidates were able to use the formula given and calculated the answer. Sometimes a mistake with the angle unit (rad or grad) on a calculator was seen.

9d and e

Most candidates were able to identify the normal force and multiply it by the coefficient of friction, but only the best candidates answered both tasks correctly. Probably due to the translation into Spanish of “state the relationship”, many answers of the kind “as the angle increases so does the friction” or vice versa, were obtained from the Spanish language variant.

10 and SL 8

Gas in a cylinder. Most of the candidates had little difficulty with most of the question. Isovolumic, adiabatic and isobaric processes with ideal gas are well mastered. In (d) a lot of superficial answers scored 1 mark only, more than “area enclosed” was required for both marks.

11 HL only

Galilean thermometer. Not an easy question, linking graph reading, Archimedes principle, average density calculation and the motion of a sphere in a liquid. Most candidates could read from the graph, some candidates were able to calculate the volume and the force, others were able to calculate the percentage filled by water and only the best students identified the net force after the change of the temperature. Most candidates tried to mention drag force, but only a few calculated the correct answer.

12 HL only

Resonance of a seed. This question was quite well answered, most of the candidates identified that the frequencies match and also most of the candidates are able to use the Q factor.

Option C

Imaging

13 and SL 9

Converging lens. A nice, complex question based on real observation and measurement. In (a) most of the candidates demonstrated the ability to use a lens as a magnifying glass, in (ii) most of the answers were focal length and not “just less than” focal length. In (b) and (c), a lens is used to make an image of an L shape object. Most of the candidates found the position of the image and were able to explain the direction of the movement of the screen to focus the image of the point Q. Some candidates were not able to calculate the vertical distance of the image of the point Q in (c ii). Identification of spherical aberration in (c iv) was also well understood by some candidates.

14 and SL 10

Astronomical reflecting telescope. Most of the candidates demonstrated that they have understood this part of the guide and have some knowledge in Newtonian and Cassegrain mountings, but many of them completed the diagram superficially and only obtained one or two marks. In (b), most of the candidates did not use scientific notation in calculations and made power of ten mistakes.

15 HL only

Step-index optic fibre. Most candidates calculated the maximum angle of light to travel through the fibre, but only the best candidates outlined the significance of the combination of refractive indexes. Many candidates mentioned graded-index optical fibres.

16 HL only

Lead screen and X-ray machine. The attenuation coefficient was calculated from the gradient of the graph by most of the candidates. In (b) only better candidates used the formula, some of them made POT mistakes.

Option D

Astrophysics

17 and SL 11

Jupiter and Vega in the night sky. (a) Nuclear fusion as the mechanism leading to light emission was identified by most of the candidates. Common mistakes were fission and burning. In (ii) most of the candidates noted that Jupiter, as a planet, is much closer and reflected light has much lower luminosity, so the brightness can be the same order, as the brightness of the much more luminous star Vega. Quite a high number of candidates wrote that both objects are the same distance from Earth.

17b

Most candidates explained constellations as a group of stars in the night sky, but many omitted to mention, that they are at different distances, not gravitationally bound. For many candidates, constellation had the same meaning as galaxy. In (ii) candidates were able to draw a diagram, but failed to show understanding, either by omitting details or by incorrectly labelling the parallax angle. In (iii) the majority of candidates manipulated the units of distance, arc sec, pc and ly.

18 and SL 12

Binary star. A well answered question, candidates seemed to have no difficulty in applying the knowledge and formulas in real situations. The only problem was in determining the radius of

Sirius B. Candidates often made arithmetic mistakes, forgot the square root or lost the 4th power of temperature. Most candidates tried to calculate the answer as a proportion of the radius of Sun. Part (e) discriminated candidates well.

19 and SL 13

A collision of galaxies. Well understood question answered more able candidates.

20 HL only

Star formation, fluctuations in CMB and critical density of the universe. Star formation is well understood by most of the more able candidates, but fluctuations in Cosmic microwave background radiation were often described only superficially gaining only some of the marks available. In (c), only a few candidates were able clearly derive the formula for critical density.

Recommendations and guidance for the teaching of future candidates

Based on the evidence gathered from the responses this session we can offer following recommendations.

Candidates score better on paper 3, if they:

- Are informed about the syllabus details at an early stage of study and check understanding of basic terms and definitions mentioned in the physics guide
- Reference topic 1 during practical work
- Are informed about standard command terms and the terms are often used in communication between teacher and student during the learning/teaching process; this seems to be equally important in teaching students who are working in mother language and in the second language
- Look for connections among topics
- Use the data booklet when solving multistep, complex problems
- Practice this paper, other past papers and specimen papers
- Are trained to express their ideas in written form, in a logical manner, in proper layout, showing each step, even if the steps seem “fully clear”
- Are encouraged to write some words explaining their working even in calculations, derivations and other use of formulas; especially in incomplete answers or alternative answers. This can be helpful for examiners and candidates can gain some marks for partially correct working; also candidates can often find their own mistake in derivations or calculations and can amend their answer
- Do not neglect units and metric multipliers; sporadically we can see even extreme POT mistakes where the resulting number makes no sense physically,
- Are encouraged to be careful with the difference between “linearly dependent” and “directly proportional”

Candidates must be reminded that every word must be legible, that the process is two ways – it is not enough to write the answer, somebody must be able to read and assess the answer.

Answers must be kept in the box or on additional sheets attached which should then be referred to.

Also, candidates should be reminded, that wrong answers are not penalized (if not in a contradiction with the right answer), so the working and answer should be crossed out only if an alternative better answer is given. Sometimes a partly correct answer is crossed and no other answer is offered by some candidates, resulting in no marks being awarded.