Physics

Timezone 2

To protect the integrity of the examinations, increasing use is being made of time zone variants of examination papers. By using variants of the same examination paper candidates in one part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the examination papers. For the May 2019 examination session the IB has produced time zone variants of Physics.

Contents

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

Grade boundaries

Higher level overall

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 25	26 - 38	39 - 48	49 - 59	60 - 69	70 - 100

Standard level overall

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 12	13 - 22	23 - 34	35 - 45	46 - 55	56 - 65	66 - 100

Internal assessment

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

Higher Level Paper one

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 12	13 - 15	16 - 18	19 - 22	23 - 25	26 - 39

Standard Level Paper one

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17	18 - 30

Higher level paper two

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 18	19 - 28	29 - 37	38 - 47	48 - 56	57 - 90

Standard level paper two

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 13	14 - 19	20 - 24	25 - 30	31 - 50

Higher level paper three

Grade:	1	2	3	4	5	6	7

Mark range:	0 - 6	7 - 12	13 - 20	21 - 24	25 - 29	30 - 33	34 - 45

Standard level paper three

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 14	15 - 18	19 - 21	22 - 24	25 - 35

Internal assessment

The range and suitability of the work submitted

Student work ranged from the simplistic (investigating resistors in series) to the innovative and insightful (determining the voltage wave form for the most efficient means to charge a capacitor). Other unique investigations include an experimental confirmation of the relativistic time dilation with cosmic rays and an investigation into the light intensity of a LEDs as a function of junction temperature. There were numerous investigations on well-known topics: viscosity and temperature, the singing wine glass, how temperature affects the refractive index of water, the coefficient of restitution of a bouncing ball, how the salt concentration in water affects refractive index, temperature and the strength of a magnet, and of course many investigations on the formation of craters. In many cases, the ideas came from existing online materials. There were also many standard investigations, like investigating cooling curves, large amplitude pendulums, the charge or discharge characteristics of a capacitor, the Atwood machine, the Gaussian gun, and a study of eddy currents.

There was a noticeable increase in the use of data-logging methods as well as video analysis. There was an increase in the use of computer simulations, such as determining the charge of an electron, the Compton effect, the photoelectric effect, colour of light and reflection intensities, real and ideal gases, real and ideal projectile motion, interference of sound. There were very few database investigations, and they were astronomical in nature. Examples included determining Hubble's parameter, the brightness of stars, and circumstellar habitable zones.

The most successful investigations had well-defined research questions, clearly identified variables with a suitable method to measure and relate them, together with 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.

Weaker investigations often had two or more independent variables. For example, dropping balls of different mass and measuring the resulting crater size usually involved larger sized balls for greater mass, and this made two independent variables. Weaker investigations often attempted too much; in fact, they were multiple investigations rolled into one: for example, an investigation into how the tension, length, diameter, and mass all affected the frequency of a musical string. Such an experiment could not provide the depth and quality needed for a well-focused IA.

Candidate performance against each criterion

Personal Engagement

The Personal Engagement criterion remains the one that is more often than not over-marked by the teacher. Some students are still writing a PE section. Not only is this inappropriate but it is often a signal for artificial interest. Top marks for PE require much more than a general interest in the topic. A love of music and measuring the speed of sound does not qualify as PE. Students have claimed to be "excited about the motion of a pendulum" or being "fascinated by Hooke's law of springs" but offered no evidence of genuine involvement. The PE descriptor "justification given for choosing the research question or topic under investigation" must be focused on the actual issues under study, not general themes like "I want to be an engineer, so I am measuring the spring constant." More importantly, PE is assessed holistically and looks for genuine depth of understanding. This includes significant independent thinking, initiative or creativity, genuine curiosity (often found in the contextual research of the RQ) and personal input and initiative in the design, implementation or presentation of the investigation. It is important for teachers to examine all the descriptors when assessing PE.

Exploration

The Exploration criterion is the most important aspect of any successful IA investigation. It is best for students to establish a well-defined set of variables, with only one independent variable. Multiple independent variables detract from a successful investigation and inhibit the student from an in-depth study. It is equally important that students understand the physics of their investigation and establish some relevant and interesting conclusions from data analysis. Often the known context of a research question was not addressed but would have been helpful to the student in order to focus and clarify their work. Academic research is expected. An example of a lack of understanding is where a student claimed that the refractive index of glass varied as the incident angle varied. Their analysis claimed this was true when angles in degrees were graphed.

Analysis

The Analysis criterion includes the traditional scientific skills of collecting and processing data, and presenting the results in a way that appreciates errors and uncertainties and which addresses the research question or purpose of the investigation. Most students demonstrated a sound mastery of analysis. 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. However, the majority of student constructed minimum and maximum gradients used only the extremes of the first and last data-point error bars. This method exaggerates the range, and in many cases produces meaningless results. The syllabus suggests minimum and maximum lines be constructed by eye for what seems a reasonable appreciation of all the error bars. Often students confused the terms linear and proportional. Also, students would claim a linear graph with a negative gradient is inversely proportional. A common fault was in assuming a scatter data set must form a linear function. Students would force a linear fit when the data did not justify this. Moreover, often data was forced into some meaningless polynomial to the 5th or 6th power. Analysis then was a purely mathematical exercise, restating the complex equation in words and never relating back to the physics of the investigation. Students often misused statistical analysis and assumed an r-squared value and other correlation statistics alone proved their conclusion. Analysis must always connect to the physics of the investigation.

Evaluation

The key to success under the Evaluation criterion is to focus on a conclusion that the data supports, including the quality of the data. Success here also requires the student to appreciate how their conclusion relates to known theory or established ideas in physics. Is it reasonable given what is already known? Finally, the evaluation criterion looks at the student's appreciation of the scope and limit of the method, details of the procedure, and possible improvements or extensions. A major improvement can be seen as an extension. Weaknesses under Evaluation include students stating purely qualitative conclusions, claiming random and systematic errors are significant without being specific, and presenting a purely mathematical statement about the data. The Evaluation criterion is the most difficult one for students to achieve high marks, and it is the one most frequently over-marked by teachers. Specific attention to all the evaluation indicators must be given.

Communication

Under the criterion of Communication, it is recommended that students write descriptive titles in their reports and not vague expressions. The title "How temperature affects the refractive index of water" is informative while "Bending light" is not. Occasionally students would produce a title page, which is not needed. Also, some students produced a table of contents, but this is also unnecessary and detracts from the flow of the report. Although the occasional photograph can help the presentation of a lab report, in most cases a sketch would be better. Students have at times included a photograph of a metre stick, themselves holding a ball, and other situations that are hard to understand. Under the expectation of a clear and concise procedure, students often wasted space by mentioning basic aspects like collecting and setting up the equipment, turning on a computer, and cookbook step by step instructions. A good individual investigation does not need these irrelevant details. Too often images taken from books or the Internet were not referenced. Communication 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. Only resources actually used should be mentioned. Students often used scientific terms with ambiguous meanings. Mass and weight, distance and horizontal displacement, speed and velocity, efficiency, and the rate of change of something were often misused.

Recommendations and guidance 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 failed to appreciate well-known theories.
- 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 the form of a question. A hypothesis is not required.
- 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. If, however, a proper function is found, then such quantities can be graphed in a linear way. 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.
- Students should not copy existing IAs as published by the IB as teacher support material, or follow detailed worksheets as published by commercial companies or purchase 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 marks. 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 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 their 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

General comments

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

Fewer of the total number of teachers or the total number of centres taking the examination returned G2's this session, at HL it was almost 15% and SL almost 10%. 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 71% (85%) of the respondents with 29% (15%) finding it too difficult. The papers were deemed to be of a similar level of difficulty as the previous year's paper by 43% (61%) of respondents, although it should be noted that both papers were considered more difficult than the previous years by 47% (32%). 71% (74%) of respondents felt that the paper was deemed to have good or better 'clarity of wording' and 89% (87%) of respondents judged the presentation to be good, or better.

This feedback was from only about 15% (10%) of the schools. From the evidence gained from the G2 comments, the examiners were satisfied that most of the questions 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 were slightly more blank responses towards the end of both papers indicating that some 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 15 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 or numbers.

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 Paper 1

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	**7034**	682	972	733	11	74.58	0.42
2	1743	2980	**3737**	836	136	39.62	0.21
3	905	**6534**	1013	904	76	69.27	0.44
4	212	794	**6154**	2258	14	65.25	0.30
5	430	**4223**	3637	1101	41	44.77	0.38
6	**7326**	899	305	894	8	77.67	0.32
7	**4883**	2167	1260	1073	49	51.77	0.54
8	1383	1113	1555	**5364**	17	56.87	0.41
9	1871	896	**3619**	3004	42	38.37	0.33
10	2121	**4077**	1940	1260	34	43.23	0.27
11	**1713**	5113	2097	472	37	18.16	0.08
12	961	599	543	**7294**	35	77.33	0.39
13	**2365**	5688	578	785	16	25.07	0.08
14	**4534**	1653	2212	955	78	48.07	0.41
15	761	1607	**6830**	218	16	72.41	0.43
16*	2686	4104	1132	1461	49	.00	0.00
17	1185	999	827	**6407**	14	67.93	0.49
18	1545	**6858**	671	345	13	72.71	0.43
19	1071	2196	1404	**4729**	32	50.14	0.45
20	1743	1751	**1694**	4167	77	17.96	0.14
21	4057	1305	2383	**1668**	19	17.68	0.09
22	**1883**	3219	2524	1726	80	19.96	0.20
23	357	**8278**	435	331	31	87.77	0.26
24	1479	776	**5291**	1843	43	56.10	0.56
25	3599	1501	1059	**3220**	53	34.14	0.35
26	**5166**	1838	1329	1063	36	54.77	0.62
27	1043	**4321**	1232	2810	26	45.81	0.49
28	637	1847	1623	**5230**	95	55.45	0.48
29	1632	2519	**3695**	1548	38	39.18	0.35
30	1088	4093	636	**3545**	70	37.58	0.37
31	1170	4359	1661	**2204**	38	23.37	0.35
32	361	1256	888	**6852**	75	72.65	0.44
33	**5480**	1680	1395	818	59	58.10	0.53
34	329	1460	**6711**	872	60	71.15	0.30
35	1382	1396	**5460**	1131	63	57.89	0.45
36	1236	**5385**	660	2065	86	57.09	0.40
37	1920	1600	2675	**3074**	163	32.59	0.23
38	695	**1669**	980	5985	103	17.70	0.13
39	3212	1380	1601	**3155**	84	33.45	0.38
40	4004	**3709**	1080	561	78	39.32	0.27

Number of candidates : 9432

Discounted questions are signified by an "*"

SL Paper 1

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	**3666**	706	1151	1030	15	55.82	0.57
2	1467	2720	**1185**	1167	29	18.04	0.15
3	124	846	987	**4598**	13	70.01	0.39
4	**2807**	342	2378	983	58	42.74	0.41
5	340	**2303**	2801	1096	28	35.06	0.31
6	610	365	**4893**	670	30	74.50	0.31
7	998	1986	948	**2612**	24	39.77	0.29
8	**2043**	2154	1033	1293	45	31.11	0.42
9	1158	940	1442	**3018**	10	45.95	0.38
10	1425	597	**2231**	2289	26	33.97	0.21
11	4716	**1177**	206	449	20	17.92	0.28
12	**2201**	1435	2379	518	35	33.51	0.51
13	681	1839	**3822**	214	12	58.19	0.55
14	1219	**3158**	894	1255	42	48.08	0.29
15	1431	**3779**	814	531	13	57.54	0.46
16	1498	289	3290	**1471**	20	22.40	0.20
17	1128	1804	1253	**2356**	27	35.87	0.32
18	385	**5019**	666	468	30	76.42	0.36
19	**3282**	1274	515	1477	20	49.97	0.44
20	2065	1489	1112	**1853**	49	28.21	0.29
21	1708	**2815**	1234	766	45	42.86	0.41
22	474	1273	948	**3826**	47	58.25	0.53
23	1910	714	714	**3199**	31	48.71	0.43
24	**2762**	1587	1368	823	28	42.05	0.45
25	1587	1714	1730	**1465**	72	22.31	0.20
26	1081	1483	**2919**	1024	61	44.44	0.37
27	2035	896	**2422**	1164	51	36.88	0.41
28	1673	**2858**	764	1190	83	43.51	0.33
29	2278	1335	680	**2208**	67	33.62	0.31
30	1222	1447	1812	**1921**	166	29.25	0.12

Number of candidates : 6568

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.

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.

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. 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.

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

SL and HL common questions

SL5, HL5

This question has a good discrimination index at HL with more candidates choosing the correct response B with C the second most popular. At SL, more candidates chose C with B the second most popular response. This question was about significant figures and candidates should be reminded that on the multiple choice paper they are not expected to perform detailed calculations. In this case 6.10 (to 3 sig figs) times 8.0 (to 2 sig figs) produces an answer to 2 sig figs giving B as the correct response. All answers are equivalent from a numerical point of view with the difference being the number of sig figs used.

SL8, HL7

This question gives good discrimination at both levels with the correct response, A, being the most popular at HL. Response B was second most popular at HL and most popular by a small margin at SL, however a significant number of candidates chose the other responses at both levels. Realising the gun and ball are initially at rest and momentum must be conserved leads to a zero momentum after firing, immediately removing options B and D.

SL10, HL9

This question has a low discrimination index at SL with more candidates choosing response D rather than the correct C. Candidates should remember that all information given in the question is important and the clue here is 'without a change in temperature'. Thus the kinetic energy does not change so internal energy and potential energy will both have the same change and in addition energy must be provided to change the state of a solid.

SL20, HL25

Most candidates at both levels gave option A as the correct response instead of D. This would indicate that they have misread the diagram thinking the voltmeter was across the 1.0Ω resistor not the parallel combination.

SL30, HL37

This had a low discrimination index at both SL and HL and although the correct answer was the most popular, all options gained high support. Candidates should be reminded that they have a data booklet and become familiar with its contents before the exam.

HL only questions

Q2

Over 100 candidates left this blank. It is testing fractional uncertainty and also involves the Heisenberg uncertainty principle.

Q10

We accept the comment from G2 forms that the wording of this question could be improved. The correct answer (B) considers the total and kinetic energies of satellite X the most popular answer.

Q11

This had a very low discrimination index with the majority of candidates choosing B, followed by C. Response A, the correct answer, was third in popularity. The candidates missed that the satellite orbits at a distance of R from the surface of a planet of radius R so the total distance to be considered was 2R.

Q13

This is a Nature of Science question and was poorly answered by candidates. It had a very low discrimination index and 60% of candidates chose response B when A was the accepted answer. The question is in the context of a real gas. For publication this will be made clearer.

Q16

This question contained an error introduced during production and was managed in standardisation. G2 comments and discussion in forums confirmed that no correct answer was present as a result. The questions is discounted for the purposes of the assessment and is corrected for publication. Overall marks for the paper are now out of 39 and a scaling factor applied.

Q20

This question had a low discrimination index with response D the most popular and an even spread between the other 3 answers. A third-harmonic standing wave of wavelength 0.8m must be on a string of length 1.2m giving 3 loops of 0.4m each. Depending on where the initial point is chosen, two points separated by 0.6m will either be in adjacent loops e.g. at 0.1m and 0.7 m with a phase difference of π or in the two end loops e.g at 0.3 m and 0.9m with a phase difference of 0. So for a standing wave there are only two possible answers, π (response C) or 0 (not included in these responses).

Q21

An unusual way of considering the Doppler effect, this had a very low discrimination index with the most popular answer A when D was correct. It is likely the candidates have confused what the train is producing – a constant intensity sound – and what the observer hears, I_o, where the intensity is going to increase as the train approaches. This immediately eliminates options A and C.

Q22

Another question with a low discrimination index and candidates choosing all 4 responses with B the most popular. Remembering that angular separation is dependent on the stars position in space relative to each other so unlikely to have been changed by a coloured filter would have helped to eliminate A and D.

Q38

A low discrimination index with the majority of candidates choosing option D when B is correct. Students tend to link the intensity of light to the number of photons but forget that it is the energy (per unit time per unit area) of the light so if the photon energy increases (frequency increases) then the number of photons must decrease.

SL only questions

Q2

The most popular answer was B giving a low discrimination index for this question. It should be a relatively straightforward question provided the candidate can remember which of 'C' or 'A' is the fundamental unit.

Q11

Most candidates chose A having forgotten to convert from °C to K.

Q16

A low discrimination index with most candidates choosing C. They have deduced, correctly, that the ray moves away from the normal on entering the denser medium but have apparently forgotten that the stem of the question has shown them that it reaches the glass-air boundary at an angle greater than the critical angle.

Q25

This question proved challenging, a low discrimination index and a relatively even spread of answers suggests that maybe guesswork was responsible for the candidates choice.

Q29

This question seems to have prompted some discussion among teachers and slightly more candidates chose response A than the others. Primary energy is defined as coming from a natural resource so whereas fossil fuels are non-renewable they are a primary energy resource. Also, a photovoltaic cell produces electricity, defined as a secondary energy source from a primary energy source, the sun. The clue is given in the question 'involve the USE of a primary energy source'.

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 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. 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

General comments

HL

From the G2 comments 90.7% of respondents felt that the paper was of appropriate difficulty, while 8.8% felt it was too difficult. 67.9 % felt that it was of a similar standard to last year's or easier, while 32.1% felt it was harder.

SL

From the G2 comments 90.7% of respondents felt that the paper was of appropriate difficulty, while 8.4% felt it was too difficult. 64.7 % felt that it was of a similar standard to last year's or easier, while 35.3% felt it was harder.

Candidates were able to show strengths in all areas of the syllabus tested by this exam paper. The sub-topics that provided the most blank answers at HL were diffraction and nuclear physics, and at SL kinetic theory of gases and black body radiation.

Many candidates' answers were well structured, and examiners again commented that there were fewer issues when it came to following lines of arguments or calculations.

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

- applying knowledge of mechanics to a novel situation
- discussing assumptions involved in the kinetic theory of gases
- Interpreting diagrams of standing waves in air columns
- detailed circuit analysis
- (HL only) changes to charged capacitors
- (HL only) understanding of the conditions required for fusion
- (HL only) diffraction
- (HL only) electric field strength calculations

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

- mechanics calculations
- ideal gas calculations
- (HL only) wave equation and Doppler effect
- basic circuit calculations
- circular motion
- explanation of the greenhouse effect
- (HL only) em induction
- (HL only) rate of radioactive decay calculations

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

1(a)(i)

At both HL and SL many candidates scored both marks for correctly answering this. A straightforward start to the paper. For those not gaining both marks it was possible to gain some credit for calculating either the change in momentum or the acceleration. At SL some used 64 ms^{-1} as a value for a and continued to use this value over the next few parts to the question.

1(a)(ii)

This was well answered although a significant number of candidates approached it using P = Fv but forgot to divide v by 2 to calculated the average velocity. This scored one mark out of 2.

1(b)(i)

This question scored well at HL but less so at SL. One common mistake was to calculate the direct distance to the top of the net and assume that the ball travelled that distance with constant speed. At SL particularly, another was to consider the motion only when the ball is in contact with the racquet.

1(b)(ii)

There were a number of approaches students could take to answer this and examiners saw examples of them all. One approach taken was to calculate the time taken to fall the distance to the top of the net and to compare this with the time calculated in bi) for the ball to reach the net. This approach, which is shown in the mark scheme, required solving a quadratic in t which is beyond the mathematical requirements of the syllabus. This mathematical technique was only required if using this approach and not required if, for example, calculating heights.

A common mistake was to forget that the ball has a vertical acceleration. Examiners were able to award credit/ECF for correct parts of an otherwise flawed method.

1(b)(iii)

This proved difficult for candidates at both HL and SL. Many managed to calculate the final vertical component of the velocity of the ball.

1(c)

As the command term in this question is 'predict' a bald answer of clay was acceptable for one mark. This was a testing question that candidates found demanding but there were some very well-reasoned answers. The most common incorrect answer involved suggesting that the greater frictional force on the clay court left the ball with less kinetic energy and so a smaller angle. At SL many gained the answer that the angle on clay would be greater with the argument that frictional force is greater and so the distance the ball slides is less.

2(a), SL 2(b)

At HL this was very well answered but at SL many just worked out E=3/2kT and left it as a value for KE.

2(b), SL 2(c)

Again at HL this was very well answered with the most common approach being to calculate the number of moles and then multiply by N_A to calculate the number of atoms. At SL many candidates calculated n but stopped there. Also at SL there was some evidence of candidates working backwards and magically producing a value for 'n' that gave a result very close to that required after multiplying by N_A.

2(c)(i), SL 2(d)(i)

This was well answered with the most common mistake being to use the volume of a single atom rather than the total volume of the atoms.

2(c)(ii), SL 2(d)(ii)

In general this was poorly answered at SL. Many other non-related gas properties given such as no / negligible intermolecular forces, low pressure, high temperature. Some candidates interpreted the ratio as meaning it is a low density gas. At HL candidates seemed more able to focus on the key part feature of the question, which was the nature of the volumes involved. Examiners were looking for an assumption of the kinetic theory related to the volume of the atoms/gas and then a link to the ratio calculated in ci). The command terms were slightly different at SL and HL, giving slightly more guidance at SL.

3(a)

This was well answered at both levels.

3(b)

Many scored full marks on this question. Common errors were using the calculator in radian mode or getting the equation upside down.

3(c)

This was very well answered.

3(d)(i) HL only

Very few candidates could interpret this situation and most arrows were shown in a vertical plane.

3(d)(ii), SL 3(d)

This was answered well at both levels.

3(e)(i) HL only

This was answered well with the most common mistake being to swap the speed of sound and the speed of the aircraft.

3(e)(ii) HL only

Answered well with ECF often being awarded to those who answered the previous part incorrectly.

4(a)

Most candidates scored both marks. ECF was awarded for those who didn't calculate the new resistance correctly. Candidates showing clearly that they were attempting to calculate the new total resistance helped examiners to award ECF marks.

4(b)(i)

Most recognised that this decreased the total resistance of the circuit. Answers scoring via the second alternative were rare as the statements were often far too vague.

4bii)

Very few gained any credit for this at both levels. Most performed complicated calculations involving the total circuit and using 12V – they had not realised that the question refers to Y only.

4(c) HL only

Most answered this correctly.

4(d)(i) HL only

By far the most common answer involved doubling the capacitance without considering the change in p.d. Almost all candidates who did this calculated a change in energy that scored 1 mark.

4(d)(ii) HL only

Very few scored on this question.

5(a)(i) and (ii)

Examiners were requested to be lenient here and as a result most candidates scored both marks. Had we insisted on e.g. straight lines drawn with a ruler or a force arrow passing exactly through the centre of the circle very few marks would have been scored. For those who didn't know which way the arrows were supposed to be the common guesses were to the left and up the page. Some candidates neglected to label the arrows.

5(b)(i)

This was generally well answered although usually to 3 sf. Common mistakes were to substitute 0.042 for F and 1 for q. Also some candidates tried to answer in terms of electric fields.

5(b)(ii) HL only

This was well answered with many candidates scoring ECF from the previous part.

6(a)

At HL this was well answered with the most common wrong answer being 'neutron'. At SL however, this was surprisingly wrongly answered by many. Suggestions given included most smallish particles, alpha, positron, beta, antineutrino and even helium.

6(b)(i)

The majority of candidates missed the fact that the figures given were the binding energies per nucleon. Many complicated calculations were also seen, particularly at SL, that involved $E = mc^2$.

6(b)(ii)

The most common mark to be awarded here was the one for linking high temperature to high KE. A large number of candidates talked about having to overcome the strong nuclear force before fusion could happen.

6(c)(i)

Well answered at HL. At SL many answers of just 'negative' were seen.

6(c)(ii)

This was poorly answered at both levels with the most common answer being zero.

7(a)

This was well answered with candidates scoring the mark for either a correct substitution or an answer given to at least one more sf than the show that value. Some candidates used 298 rather than 289.

7(b)

For many this was a well-rehearsed answer which succinctly scored full marks. For others too many vague terms were used. There was much talk about energy being trapped or reflected and the ozone layer was often included. The word 'albedo' was often written down with no indication of what it means and 'the albedo effect also featured.

7(c)(i) HL only

This was well-answered, a very straightforward 2 marks.

7(c)(ii) HL only

Many candidates didn't understand this question and thought that the answer needed to be some form of human activity that would reduce global temperature rise.

8 HL only

8(a)

This was generally well answered by those who attempted it but was the question that was most left blank. The most common mistake was the expected one of simply doubling the intensity.

8(b)

This was very well answered. As the question asks for the answer to be given in nm a bald answer of 560 was acceptable. Candidates could also gain credit for an answer of e.g. 5.6×10^{-7} m provided that the m was included.

8(c)(i)

Many recognised the significance of the single slit diffraction envelope.

8(c)(ii)

Credit was often gained here for a calculation of an angle for alternative 2 in the markscheme but often the final substitution 1.50 was omitted to score the second mark. Both marks could be gained if the calculation was done in one step. Incorrect answers often included complicated calculations in an attempt to calculate an integer value.

9 HL only

9(a)(i)

This was generally well answered but with candidates sometimes getting in to trouble over negative signs but otherwise producing well-presented answers.

9(a)(ii)

A large number of candidates thought that the total energy of the planet would change, mostly double.

9(b)

The majority of candidates had an idea of the basic technique here but it was surprisingly common to see the squared missing from the expression for field strengths.

10 HL only

10(a)

This was well-answered.

10(b)

Answers here were reasonably evenly split between clockwise and anti-clockwise, with the odd few arrows pointing left or right.

10(c)

The majority of candidates recognised that the magnetic force would be upwards and the most common way of explaining this was via Lenz's law. Students needed to get across that the force is opposing a change or a motion.

11 HL only

11(a)

This question could have simply asked for the differences but did not puzzle the students who, when scoring, referred successfully to the differences between Bohr's postulate and de Broglie quantification of the wave like characteristics. Examiners marked this question without reference to particular physicist or what individuals suggested. As a result many scored the first mark for suggesting that electrons have wave like properties. The rest of the answers then commonly restated the stem of the question about a well-defined radius.

11(b)(i)

Many candidates answered this well but calculated the diameter rather than the radius.

11(b)(ii)

Many scored the first mark but it was rare to see answers that talked about the strong nuclear and electrostatic forces.

11(c)(i)

Many scored the first mark for calculating the number of nuclei but neglected to convert λ to s^{-1}.

11(c)(ii)

This was very well answered with the majority of candidates scoring full marks. This is a good indication that candidates weren't short of time in this paper.

SL only

2(a)

The mark was awarded for a clear substitution or an answer to at least 3sf. Many gained the mark for a clear substitution with a conversion from g to kg somewhere in their response. Fewer gave the answer to the correct number of sf.

3(c)(i)

Many used a ratio of the speeds to produce a new frequency of 14Hz (340 x 250/6010). It would have helped candidates if they had been aware that the command term 'state' means 'give a specific name, value or other brief answer without explanation or calculation.'

Recommendations and guidance for the teaching of future candidates

- Encourage candidates to read the examination questions carefully.
- Encourage candidates to look at the number of marks available and judge how much detail is required in their answer.
- Encourage candidates to show workings in calculations, in particular so that examiners have the opportunity to award 'error carried 'forward' marks. This was particularly important in the mechanics calculations in this exam.
- Encourage candidates to show a sufficient number of significant figures in their answers to 'show' questions. In other words, at least one more than the 'show' value given in the question.
- Encourage candidates to take care when drawing and labelling diagrams or features on diagrams
- Encourage candidates to have a thorough knowledge of the symbols used in the data booklet.

Paper three

General comments

Most candidates made a serious effort to attempt the required number of questions and appeared to have ample time to complete the paper. Virtually no candidates attempted more than one Option. On rare occasions the whole Section A was unanswered. Relatively few candidates allowed answers to flow outside the boxes provided on the question paper. There are still too many candidates who do not know how to present answers within answer boxes in an organised way. This session saw fewer extension sheets used - possibly by only 15% of candidates. In many schools no extension pages were used at all. This may be due to larger answer boxes, but in a few cases, it is clear that candidates are given instructions on the correct use of answer boxes in schools. Some candidates believe that the more they write, the better is their chance of saying something that will earn marks. The reverse is often true.

Examiners appreciate concise answers that are not contradictory and do not deviate from the question. There were frequent occasions when poor handwriting made marking difficult. In particular powers of ten and decimal points were not always clear. Very often examiners had difficulty in deciphering the candidate's reasoning within a calculation – and frequently this reasoning was completely absent. Errors with units and powers of ten were alarmingly frequent.

Nearly 160 schools provided G2 P3 feedback for the HL paper and 105 schools for SL. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. 94% of schools thought that the paper was of appropriate difficulty at HL and 96% at SL. For HL, 63% of schools thought the paper was of similar difficulty to last year; 21% thought it more difficult, 16% thought it was easier. For SL, 70% of schools thought the paper was of similar difficulty to last year; 23% thought it more difficult, 7% thought it was easier. The overall comments on the individual options suggests that the majority of schools responding were satisfied with the balance and facility of the paper.

General areas that need improvement:

- Powers of 10 and unit multipliers. (The most common cause of accidental mark loss)
- Careless arithmetic and algebraic errors. Calculator mistakes are common.
- Showing working in full in 'show that' questions. Proof of calculation is required
- especially if the answer is given in the question.
- Handwriting is often very poor.
- General layout of working in numerical questions needs to be legible, planned and
- methodical.
- Students should realise that marks are frequently allocated for showing steps in the
- working. Some scripts were almost impossible to mark because working was scattered
- all over the answer box.
- Paying attention to the number of marks awarded for each part question. Often
- candidates provide fewer key facts than required.
- Sequencing the presentation of facts to support an explanation or description. The
- answers should form logical, concise and coherent arguments. The use of bullet points
- was rarely seen but is often helpful. Many candidates write far too much hoping that at
- least some of what is written will score marks, but this often results in contradiction.

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

- Realising what the physical significance of an intercept is.
- Determining the fundamental units of a physical quantity.
- Linearisation of graph.
- Manipulation of units (often units are ignored by candidates , but they are still tested).
- First postulate of special relativity.
- Use of Lorentz transformations.
- Problems involving 3 frames of reference.
- Time dilation.
- Calculations involving relativistic mechanics and using units (HL).
- Balancing moments (torques).
- Estimating work done by counting area of squares under a PV curve (especially at
- SL).
- Calculation of change as ‘final value - initial value’.
- Limiting pulse rate in fibres.
- Processes in a Cepheid variable.
- Electron degeneracy in white dwarf stars (especially at SL).
- Derivation of cosmological formulae (HL).

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

- Propagating uncertainties.
- Proper length
- The twin paradox.
- Gravitational redshift (HL).
- Rotational motion.
- Forces on a sphere falling in a viscous fluid (HL).
- Resonance (HL).
- Ray diagrams.
- Step index and graded index fibres.
- Dispersion and attenuation in fibres.
- Uses of ultrasounds (HL).
- Stellar calculations.
- Stellar processes.
- Type 1a Supernova (HL).

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

Section A

1(a)

Almost all candidates realised that the uncertainty in I was too small to be shown. A common mistake was to mention that since I is the independent variable the uncertainty is negligible.

1(b)

The number of candidates who realised that the V intercept was EMF was disappointing. Large numbers of candidates tried to calculate ε using points on the graph, often ending up with unrealistic values. Another common mistake was not giving values of ε and Δε to the correct number of digits - 2 decimal places on this occasion. Very few candidates drew maximum and minimum gradient lines as a way of determining Δε.

2(a)

M0ost candidates correctly drew curves which passed through all the error bars, some tried to draw straight lines. Quite a few did not draw any line, leaving the question unanswered. Candidates need to make sure to check that they read the question paper carefully.

2(b)(i)

Determining the fundamental units of K (kg-1 m-1) was difficult for most candidates.

2(b)(ii), 2(b)(iii)

These questions were not well understood, but a few candidates were able to state that a plot of f2 versus T would give a straight line through the origin.

3(a)

A very easy question about percentage uncertainty which most candidates got completely correct. Many candidates gave the uncertainty to 4 significant figures or more. The process used to obtain the final answer was often difficult to follow.

3(b)

The most common correct answer was the readings should be repeated and an average taken. Another common answer was that D could be increased to reduce uncertainties in s. The best candidates knew that it was good practice to measure many fringe spacings and find the mean value. Quite a few candidates incorrectly stated that different apparatus should be used to give more precise results.

Option A Relativity

4(a)(i)

In defining an inertial frame of reference far too many candidates started with the words ‘ a frame of reference that...... ’ instead of ‘a coordinate system that.....’

4(a)(ii)

Almost no incorrect answers were seen.

4(b)

Most candidates correctly stated that in special relativity the velocity of light, c, is the maximum possible velocity or is invariant. Only a few added that Galilean relativity only applies at speeds much less than the speed of light.

5(a), 5(b)

Candidates usually realised that the magnetic field was due to the motion of the protons and that in the proton rest frame there could be no magnetic field. The answers were too often poorly worded and the candidates appeared to reword the question without providing a clear explanation.

5(c)

A few candidates mentioned that there was an electrostatic repulsive force between the protons in both frames. However very few realised that there **had** to be an overall repulsive force in both frames because of the relativity postulate.

6(a)

Proper length is quite well understood. A common mistake is to mention that it is the length measured by a reference frame at rest.

6(b)(i)

Because there were three frames of reference in this question many candidates struggled to find the simple value for the time of the ball's travel down the train in the train's frame of reference.

6(b)(ii)

Almost no candidates could use a Lorentz transformation to find the time of the ball's travel in the frame of reference of the platform. Most just applied some form of $t=\gamma t'$. Elapsed time and instantaneous time in different frames were easily confused. Candidates rarely mention which reference frame is used when making calculations, however this is crucial in relativity.

7(a)

Most candidates could show that the velocity of the spacecraft was 0.8c.

7(b)

Event E was usually correctly labelled on the space-time diagram.

7(c)(i)

A very simple time dilation question which most candidates got wrong at SL but the question was better answered at HL.

7(c)(ii)

Many candidates tried to use time dilation again without realising that the clock on P must also read 5 years at event E because that is the time on the Earth clock in P's frame for the event.

7(d)

The twin paradox is now well understood and there were some good quality answers. Some candidates even knew that the Earth clock jumps forward when the Astronaut turns around.

HL 8(a)

Generally well answered by most candidates. A common mistake was to define the total energy in the context of classical mechanics.

HL 8(b)(i)

Most candidates seemed to have the right starting points but mistakes were often made in attempting to convert units. The energy-momentum equation is generally best answered using only 'MeV' based units.

HL 8(b)(ii)

An easy calculation, that was generally well answered.

HL 8(b)(iii)

Very few candidates realised that this question required a simple calculation using $eV = KE = (\gamma - 1)E$.

HL 9(a)

Most candidates answered this question correctly using the equivalence principle and could show that the frequency would decrease.

HL 9(b)

Arithmetic mistakes were common at the different stages of the calculations even when the process used was correct.

Option B Engineering Physics.

10(a), SL 8(a)

Many candidates stated that the resultant of all forces must be zero but failed to mention the fact that horizontal forces must balance in this particular question.

10(b), SL 8(b)

Very few candidates could take moments about any point and correct answers were rare both at SL and HL.

10(c), SL 8(c)

The question about the slipping of the ladder was poorly answered. The fact that the normal reaction on the floor was 50N was not known to many.

11(a), SL 9(a)

The derivation of the formula for the total kinetic energy of a rolling ball was well answered.

11(b), SL 9(b)

Although there were many correct answers, many candidates forgot to include the initial kinetic energy of the ball at the top of the ramp. The process followed to obtain the answer was too often poorly presented, candidates are encouraged to explain what is being calculated rather than just writing numbers.

12(a), SL 10(a)

At SL, Correct answers were rare and very few candidates used the fact the work done was area under the curve, and even fewer could estimate this area. At HL, the question was better answered. Candidates used a range of methods to estimate the area including counting the squares, approximating the area using geometrical

shapes and on a few occasions using integral calculus.

12(b)(i), SL 10(b)(i)

Not very many candidates seem to know the generalised formula ΔU =1.5(P2V2 -P1V1) however many correct answers were seen.

12(b)(ii), SL 10(b)(ii)

The temperature at A was found correctly by most candidates.

12(c), SL 10(c)

The main problem here was deciding whether each Q was positive or negative. But the question was quite well answered.

12(d), SL 10(d)

Because the question was about a heat pump rather than a heat engine very few answers were correct. Only a very small number of candidates mentioned the fact that the isothermal change would take an impracticably long time.

HL 13(a)

The question was generally well answered but many candidates did not realise that the drag force would only be present when the ball starts moving.

HL 13(b)

Many candidates could explain correctly that the drag force would increase as the speed increases and that the weight would be balanced by the buoyant force and the drag force.

HL 13(c)

When the condition for forces in equilibrium was correctly formed, many candidates managed to obtain the correct answer. The working was often poorly presented making it difficult to mark or award marks for the process.

HL 14(a)

The question was correctly answered by almost all candidates.

HL 14(b)

The answers to this question were generally well presented and a correct argument was presented by almost all candidates. Resonance was often correctly referred to.

HL 14(c)

A correct curve, with lower amplitude and shifted left, was drawn by most candidates.

Option C Imaging

15(a)(i), SL 11(a)(i)

The simple ray diagram was constructed well by most candidates, especially compared to previous years.

15(a)(ii), SL 11(a)(ii)

The very simple calculation of magnification was done well by nearly everybody.

15(a)(iii), SL 11(a)(iii)

Using a converging lens as a magnifying glass was the most common correct answer.

15(b)(i), SL 11(b)(i)

Another very easy and well answered ray diagram question.

15(b)(ii), SL 11(b)(ii)

Only candidates who realised that a simple telescope was being constructed were able to answer the question correctly. Most candidates realised that the focal lenses need to be added but few found the focal lens of the second lens correctly.

15(b)(iii), SL 11(b)(iii)

Many candidates did not read the question carefully and provided totally incorrect answers. It does not seem to be generally well known that if a distant object is moved to the right, for a converging lens, then the real image must also move to the right.

16(a), SL 12(a)

The differences between step index fibres and graded index fibres seem well-known.

16(b)(i), SL 12(b)(i)

The calculation of the difference in the speed of light for two different wavelengths was well answered. Candidates often rounded answers to a small number of significant figures when finding the individual speeds.

16(b)(ii), SL 12(b)(ii)

Most candidates correctly drew a wider pulse with smaller area.

16(b)(iii), SL 12(b)(iii)

Correct answers mentioning dispersion and attenuation were common but few candidates were able to relate those phenomena to the shape of the pulse drawn.

16(b)(iv), SL 12(b)(iv)

Most candidates did not mention the fact that if the time between

pulses was too small then the pulses would overlap for longer fibres.

HL 17(a)(i)

The question was well answered by almost all candidates.

HL 17(a)(ii)

Most candidates mentioned that the gel improves the transmission of ultrasound. On quite a few occasions candidates seemed to confuse acoustic impedance and refractive index.

HL 17(a)(iii)

The question was generally well answered with a few candidates simply taking the ratio of intensities instead of 10x log ratio (Intensity **level**)

HL 17(b)(i)

Almost all candidates managed to obtain the result given.

HL 17(b)(ii)

Many candidates did not seem to know how to start answering the question. The factor of two was often omitted when finding the depth of the organ in the A scan.

HL 17(b)(iii)

Few candidates managed to understand how to approach the problem and to obtain the correct answer. ECF from bii was frequently need.

HL 17(b)(iv)

Most candidates mentioned that the resolution would be better at higher frequencies.

Option D. Astrophysics

18(a)(i), SL 13(a)(i)

The expansion and contraction of Cepheid stars was commonly mentioned. Changes in surface temperature and opacity were less commonly mentioned. A common misconception seems to be that the variation of luminosity is due to a change of the rate of fusion. A few candidates left this question unanswered.

18(a)(ii), SL 13(a)(ii)

Many candidates knew that if the luminosity of the Cepheid is known then the absolute brightness can be used to determine distance. But far fewer candidates could link luminosity with the period of the Cepheid star. Many seemed to think that the luminosity of **all** Cepheids is the same.

18(b)(i), SL 13(b)(i)

Calculating the brightness of a star from its luminosity was an easy question for most candidates. But quite a few did not convert parsecs into metres

especially at SL.

18(b)(ii), SL 13(b)(ii)

This simple calculation using Wien's law was very well answered.

18(c), SL 13(c)

Many candidates correctly stated that astronomers can use peer review or different methods in checking that the information obtained from stars is correct.

19(a)(i), SL 14(a)(i)

This very simple application of Hubble's law was answered correctly by the vast majority of candidates.

19(a)(ii), SL 14(a)(ii)

Many candidates subtracted the change in wavelength and obtained a blue shift. Others were unsure which wavelength λ_0 is in the data book equation. But correct answers were common.

19(b), SL 14(b)

Nearly all candidates were able to mention redshift as the evidence for galaxy recession and the universe expansion.

20(a), SL 15(a)

Locating the Sun's position on the HR diagram was correctly done by most candidates, although a few were unsure of the surface temperature of the Sun.

20(b), SL 15(b)

The evolution of a main sequence star to the red giant region is reasonably well understood. However many struggled to find three different facts to describe the changes. Answers were often too vague, when writing about a change in temperature or size of a star, the candidates are expected to mention whether they are referring to the core or the surface/outer layer. A surprising number of candidates wrote that the Sun must be less than eight solar masses.

20(c), SL 15(c)

The mention of electron degeneracy pressure was fairly common, but incorrect answers were even more common at SL.

20(d), SL 15(d)

Calculating the ratio of the radius of a white dwarf to a red giant star was done quite well by most candidates. However quite a few candidates made POT errors or forgot to take the final square root.

HL 21(a)

The formation of Type 1a supernovae was well known by most candidates but few were able to explain how this process resulted in a standard candle.

HL 21(b)

Many candidates could describe the r process correctly but quite a large number of candidates seemed completely at a loss and could not relate the r process to neutron capture.

HL 22(a)

The vast majority of the candidates could state that the total energy is equal to the sum of the kinetic and potential energies but quite a few did not use the correct formula for the gravitational potential energy. The formula for the mass of the sun was usually correctly substituted.

HL 22(b)

This was a relatively easy demonstration given the equation in 22a. However many candidates did not show the process followed in a coherent manner that could be understood by examiners.

HL 22(c)

The question was well answered by many candidates.

Recommendations and guidance for the teaching of future candidates

Now that candidates are allowed to answer questions from only one of the four options it is vital that schools select an option that is popular and suited to the abilities of both candidates and teaching staff. Some option topics may include material that staff have never taught or even seen before. It is important that sufficient time is allocated to the learning of the chosen option. It seems that many students would benefit from being shown more examples of neat, concise and logically structured answers particularly when answers have to be fitted into the limited space of an answer box. Use of the answer box is a skill that needs to be actively taught. In many schools model answers to homework questions are often provided and these homework questions are often taken from past IB exam papers. It would be helpful if such questions included an answer box so that plenty of practice is available throughout the 2 year course.