May 2016 subject reports

Physics

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-13	14-25	26-35	36-44	45-54	55-65	66-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-13	14-23	24-33	34-43	44-54	55-64	65-100

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Higher level and standard level internal assessment

Component grade boundaries

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

The range and suitability of the work submitted

The range of student work covered a spectrum of investigations, ranging from basic to most impressive. At one extreme there was an IA measuring the effect voltage has on current for a fixed resistor, the impact speed of a free-fall ball related to the drop height, and another on determining a spring constant. These investigations were too basic and too obvious to earn high marks under Exploration. Sometimes teachers allowed students to follow one of the prescribed investigations. These are generic investigation requirements, meaning that the details of method and technique are up to the teacher or student. As such, a required investigation could be a starting point for an IA, although the teacher needs to be careful doing this. For example, the student knows about the length of a simple pendulum and the period of oscillation but then decides to investigate large displacement angles where the basic equation no longer holds. This would be a justified extension of a generic investigation. On the more impressive end of the spectrum of investigation types there was a database investigation establishing the circumstellar zones for certain stars. Bifilar pendulums were popular, as was the variation of refractive index as a function of a liquid density. Computer simulations were used to determine the charge of an electron, to measure the universal gravitational constant, and other physics quantities that would normally be difficult to determine in the classroom. There were some original investigations too, including a study of Tsunami effects, the permeability of free space, the angle of liquid in a container under acceleration, and variations on the Doppler effect.

The majority of student work involved hands-on investigations, with primary data collection in the school laboratory. This approach allowed addressing all the assessment criteria. Mechanics was the most popular topic, but electricity and magnetism, waves, and astrophysics were common too. A surprisingly low number of investigations were mathematical models, computer simulations and database investigations.

Candidate performance against each criterion

Personal Engagement Strengths:

When a student report demonstrates independent thinking, initiative or creativity, and when there is personal significant, interest and curiosity in the chosen research question, and when there is personal input in the design or implementation or presentation of the investigation, then the student has addressed the personal engagement criterion. PE is assessed holistically.

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 PE descriptors.

Personal Engagement Weaknesses:

Students would often over-emphasized ‘personal significance’ by writing what seemed to be artificial comments about their interests. Teachers need to encourage students to demonstrate their curiosity and insight in the investigation itself, in the nature of the research question, in the details of methodology and analysis, and in other contributions made by the student to their individual investigation. Teachers often over marked PE thinking that an interest in the general topic was enough to earn full marks. Because PE is assessed in a holistic way, students should not add a sub-title section “Personal Engagement.”

Exploration Strengths:

Many students produced interesting and challenging investigations. These always included a single and well-defined independent variable and a quantifiable dependent variable. Appropriate investigations often made use of known scientific concepts and equations. As a result, analysis was focused in a relevant way. Issues of safety, ethical and environmental concerns were mentioned when appropriate. Moderators were impressed by the degree of student engagement and imagination.

Exploration Weaknesses:

Some students had vague research questions, never defining the key issues. Some investigations had multiple independent variables. This usually harmed the quality of the investigation as it took the student’s attention away from a more focused study. Some students made up a scientific context, following common sense when there was relevant theory but never realized by the student.

Some investigations were too simple and the research question too obvious, like finding the spring constant for a rubber band or investigating the impact speed from free fall at different heights. An inappropriate question was “Which is more efficient: boiling water with an electric kettle or boiling water in a pot on the stove?” Or, “What type of ball bounces the highest?” More appropriate research questions look for functions or relationships between two variables, or to determine an important constant in nature. Occasionally students thought that a history of physics provided background when in fact all it did was distract the focus of the investigation.

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

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methodological issues. These are traditional scientific skills, and the majority of students demonstrated a sound mastery of analysis. The majority of students demonstrated the ability to obtain and record data, including raw uncertainties. Data tables were clear and consistent with scientific notation. Processing was often detailed, with sample calculations. Graphs were nicely presented often with error bars. The majority of student graphs were computer generated. In most cases theory and hypothesis directed the appropriate graph representation. Often students used more advanced methods of error analysis, and this was successful.

Analysis Weaknesses:

Occasionally raw data was incorrectly recorded, omitting uncertainties. Column headings should include the quantity, units and uncertainty. Occasionally incorrect units, such as feet and minutes, were used. Claiming a metre rule could measure distances to 0.01 mm is unlikely to be true. Some graphs lacked appropriate detail, and some graphs were too small to appreciate. This would affect the Communications assessment. In some cases, data scatter suggested a curve and yet the student forced a linear fit. The linear fit was then used to establish a conclusion. One student thought they established a linear relationship between the length of a pendulum and the period. Teachers should encourage students to consider how the relevant theory applies and how the graph should look. Considering what the *x* and *y* intercepts mean in terms of the physical properties under study. Students need to be careful when claiming results prove something. There should always be a range and limit to the meaning of a given investigation.

Evaluation Strengths:

The evaluation criterion remains one of the hardest criterions to address for many students. Focus is the key here and students who justified a conclusion for their investigation based on the original research question did well. The propagation of uncertainties was a key part for successful students. When there is a known scientific context or accepted value, then students who compared their result with the accepted value did better. The more successful student reports showed an appreciation for any assumptions in their methodology.

Evaluation Weaknesses:

Students need to be careful with statements about proving a hypothesis. An appreciation of the scope and limit, the methodology and any theoretical assumptions should be addressed when evaluating a conclusion. Often the terms proportional and linear were confused. 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. Too often students would force data to fit a linear graph and then state this as a conclusion with the linear line as the justification. In an Evaluation students need to appreciate the physical meaning of the quantities under investigation, and so they need to interpret the data correctly. Many times 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.

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Communications Strengths:

Communications, like Personal Engagement, is assessed holistically. This means that the overall clarity, flow and focus of the report is 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. The best reports had specific titles, like “How the temperature of a rubber band affects its spring constant” and not generic titles like “Investigating Machines.” The majority of reports used correct and relevant scientific notation, equations and units. The majority of reports were within the 6 to 12-page expectation. 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 or how much a student enjoys physics class).

Communications Weaknesses:

A number of students omitted any sort of investigation title. Some students wrote “IA Investigation” or vague titles like “Investigating Light.” A cover sheet is not necessary. A table of contents may give the reader an overview but is not necessary either. Significant sections relating to personal interest and the history of science often contributed little to the achievement of the student. Investigations need to refer to the research question early. Step by step instructions were too detailed in some cases and unnecessary. Students do not need to include a photographs of a metre rule or a stopwatch. This can lead to wasted space. Often reports with excessive content (e.g. 16 or 18 pages) inhibited the clarity of the report. Occasionally students would copy pictures from the Internet or a textbook and not give the reference. In some cases, this was obvious, but referencing is required for all material that is not original. Communications does not penalize for lack of references but rather when this occurs it becomes an issue of academic honesty.

Recommendations for the teaching of future candidates

It is important that teacher provide guidance during the entire IA investigation process, and not only when they read the first draft. Some of the problems that teachers could correct early on include multiple independent variables, unquantifiable variables, graphs with scatter data suggesting a curve but students forcing a linear fit, inappropriate units or even no units, and too simple a research question. Teachers could also make sure students include a descriptive title to their investigation, and that students do some academic research to find out the relevant known theory to their own work. A number of investigations could have been improved if the student had this support early on.

Further comments

The majority of schools are doing appropriate IA work and teacher’s assessment is fair. The majority of teacher’s marks were within the acceptable range. Students are working hard. There was a large range of work quality and a wide range of types of investigations, including

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database, simulations and mathematical models. This is encouraging, and schools, teachers and students have successfully embraced the new IA system. The key to IA success is to have a well-defined and focused research question that is challenging and interesting to the student.

Some topics of individual investigations that earned high marks include: large amplitude pendulums, temperature and the internal resistance of a battery cell, the fate of stars in Ursa Major (database), Hubble's law (database), Rayleigh scattering (physical and mathematical models), transformer efficiency and frequency, RC circuits and manufactures values, magnetic braking of a pendulum, optimal mass of water in a water rocket, limitations of the Bohr model (model and experiment), measuring speed with the Doppler effect, speed of sound through different materials, temperature and the mirage effect. In all cases it was a scientifically interesting and well-focused research question along with competent analytical skills that earned high marks, not a particular topic.

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Higher level and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-13	14-17	18-20	21-23	24-28	29-40

Standard level

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

General comments

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

Every year there are occasional comments from teachers that either paper 1 or paper 2 are unbalanced in terms of syllabus cover. It should be noted, however, that these two papers *together* aim to provide valid assessment of the complete syllabus, both in content and skills. The specific skills that need to be engendered in the candidates in order to succeed at multiple choice questions are described in the final section of this report.

A very pleasing percentage of the total number of teachers or the total number of centres taking the examination returned G2's. For SL there were 373 responses from 1425 centres (26%) and for HL there were 491 responses from 1211 centres (40%). We recognise that this large response was the result of the new syllabus and hope this level of response continues.

The HL (SL in brackets) paper was regarded as being of appropriate difficulty by about 60% (64%) of the respondents. Over 70% of all respondents regarded this paper as being more difficult than last year's paper. Both papers were regarded as having good, or better, 'clarity of wording' by around 65% of respondents; and over 80% or teachers judged the presentation to be good, or better.

This means that about one third of the teachers were unhappy with the wording of the questions. There was also a feeling, albeit by a minority of teachers (20% in HL and 15% in SL), that the wording was inappropriate for second language learners and those with learning difficulties.

The responses from the teacher feedback can be distilled into a three main categories.

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Time

There were many comments that there was not enough time as the questions were more ‘multi-layered’ than in previous years. The new syllabus, however, specifies that 50% of multiple choice questions will require AO3 skills. This is a departure from previous practice and students should expect some questions to be done in well under a minute leaving extra time for those questions of greater complexity.

Although the examiners always encourage the students not to leave blanks, we have previously taken a large number of blanks as an indication that the paper was too lengthy. It is interesting that the percentage of blanks recorded in this year’s papers was very much in line with previous years.

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. Indeed, a paper that just offers students familiar questions would not be a physics paper. 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.

Wordiness

The examiners recognised that a number of the early questions were of a wordy nature and that this meant that some students got off to a ‘bad start’.

Paper writers and reviewers do their utmost to ensure that words are kept to a minimum and supplement the question with a diagram where helpful. But all the words in a multiple choice question are important so students must be encouraged to carefully read the question rather than jumping to conclusions too early.

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 (correct option) is indicated by a shaded cell.

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 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

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proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

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Higher level paper one item analysis

Number of candidates: 11261

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	2030	5797	2663	661	110	51.48	0.35
2	9129	1038	360	722	12	81.07	0.23
3	4258	1646	1541	3769	47	33.47	0.44
4	3260	2001	3073	2900	27	28.95	0.41
5	775	3655	2939	3851	41	34.20	0.15
6	374	1964	7502	1353	68	66.62	0.44
7	2069	6727	1984	357	124	59.74	0.61
8	5553	2594	2214	855	45	49.31	0.47
9	423	3883	1860	5043	52	34.48	0.10
10	2750	1939	1026	5503	43	48.87	0.39
11	865	2768	1650	5952	26	52.85	0.43
12	1921	1754	6367	1142	77	56.54	0.49
13	5880	3908	932	503	38	52.22	0.35
14	322	1422	7177	2324	16	20.64	0.23
15	1692	1104	6800	1629	36	60.39	0.44
16	3892	1609	4310	1420	30	38.27	0.41
17	3238	5889	495	1584	55	28.75	0.15
18	1259	921	2529	6471	81	57.46	0.44
19	1333	8873	913	134	8	78.79	0.61
20	2070	3519	2051	3474	147	30.85	0.47
21	7262	1860	1166	930	43	64.49	0.10
22	3602	470	6773	405	11	60.15	0.39
23	1789	5383	1327	2611	151	47.80	0.43
24	6407	2135	1222	1439	58	56.90	0.49
25	835	291	5748	4358	29	38.70	0.27
26	3762	6998	219	230	52	62.14	0.19
27	1958	1767	6137	1258	141	54.50	0.51
28	1003	7576	936	1699	47	67.28	0.20
29	2634	2228	3565	2754	80	23.39	0.36
30	1073	3312	5982	678	216	53.12	0.43
31	617	3357	5526	1664	97	49.07	0.34
32	3525	2500	1520	3612	104	31.30	0.42
33	839	2030	2568	5716	108	50.76	0.43
34	1671	711	7059	1736	84	62.69	0.41
35	1420	6479	664	2628	70	57.53	0.31
36	1471	3031	2275	4267	217	37.89	0.52
37	1492	4894	1836	2863	176	43.46	0.50
38	1516	1503	6771	1301	170	60.13	0.00
39	1571	7479	1319	737	155	66.42	0.26
40	4819	942	4116	1227	157	42.79	0.47

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Standard level paper one item analysis

Number of candidates: 11634

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	2849	5004	2823	805	153	43.01	0.31
2	1248	3348	1865	5050	123	43.41	0.59
3	8002	1609	901	1105	17	68.78	0.36
4	5048	2064	1852	2573	97	22.12	0.25
5	2404	2944	5619	622	45	25.31	0.25
6	784	1030	8329	1417	74	71.59	0.26
7	2453	2982	2359	3776	64	21.08	0.23
8	912	3512	3114	4054	42	34.85	0.20
9	880	2861	5843	1944	106	50.22	0.45
10	2452	5231	2247	1637	67	44.96	0.37
11	2445	4199	2877	2062	51	36.09	0.31
12	3620	3694	2853	1380	87	31.12	0.32
13	3421	4547	2230	1365	71	29.41	0.43
14	4623	1066	4681	1228	36	40.24	0.33
15	720	4257	998	5557	102	36.59	0.05
16	2503	2674	1922	4440	95	38.16	0.22
17	1070	3159	2566	4797	42	41.23	0.39
18	1753	6211	2611	989	70	53.39	0.43
19	444	661	9934	552	43	85.39	0.15
20	5858	3051	1153	1473	99	50.35	0.47
21	4538	3187	2310	1460	139	39.01	0.31
22	545	2102	7152	1763	72	15.15	0.15
23	6631	2039	1068	1756	140	57.00	0.49
24	2459	1951	4389	2644	191	37.73	0.34
25	1943	5327	3412	828	124	45.79	0.37
26	3559	1793	4058	2062	162	34.88	0.23
27	1099	1235	5925	3213	162	50.93	0.36
28	1528	2001	3364	4414	327	37.94	0.39
29	2090	7229	1755	397	163	62.14	0.44
30	2433	3200	2930	2622	449	22.54	0.22

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

Candidate performance on the individual questions is provided in the statistical tables above, along with the values of the indices. For most questions, this alone will provide sufficient feedback information when looking at a specific question. Feedback will be given only on selected questions, i.e. those that illustrate a particular issue or drew comment on the G2's.

SL and HL common questions

SL Q1 and HL Q1

The *percentage* uncertainty for all volumes will be three times the percentage uncertainty of a linear measurement. Since this is the same for the sphere as well as the cube the answer can only be B.

Some G2 comments thought this was too difficult as it involved calculating the volume and was too complex for a first question. But this question can be done in a moment by those students who are aware of the concept involved and who do not automatically think physics is about calculations.

SL Q3 and HL Q2

Candidates are expected to select the best answer. A few teachers wondered about the exact time scale for the horizontal axis, but the vast majority of candidates realised that when the ripcord is pulled then the speed will suddenly reduce – but not change direction! Hence it can only be A.

This was a graphical question. Students should always look at the axes first and be encouraged to translate graphs into words describing what is being represented.

SL Q4 and HL Q3

The examiners realised that a diagram may have added to the clarity of this question.

Students need to understand the 'message' that trigonometric functions are giving. Sinθ is an increasing function with a maximum of 1 whereas cosθ is a decreasing function. Tanθ is increasing but with no maximum – becoming infinitely large as θ increases to 90^0.

As θ_0 increases to 90^0 so the normal force decreases – so B and C can be discounted. If θ_0 becomes 90^0 and the object still hasn't fallen, then clearly it is stuck onto the plane with glue! This must mean an infinite coefficient of static friction. Hence D.

Response A was a common choice, but this would give a finite μ at 90^0 when N = 0

The G2 comments suggested that it would be too time-consuming for the candidates to draw the diagram and do the necessary analysis involving the resolution of forces, from scratch. But this is <u>not</u> needed! Students should avoid tackling multiple choice questions as though they were alternative paper 2 questions.

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The whole purpose of multiple choice questions is to get the candidates to assess options.

SLQ7 and HLQ4

The question is very clear that u and v refer to speed. As the force on the wall is positively related to the incoming and the outgoing speeds both C and D can be eliminated. B will involve a term in uv when multiplied out. This would clearly be nonsense, so it must be A.

Some teachers regarded this as a 'trick' question, but the examiners thought it entirely reasonable that candidates should be alert to the difference between *speed* and *velocity* when reading multiple choice questions.

SL Q8 and HL Q5

The power developed by a vehicle is the product of its *speed* and the *force* with which it is pulling. As time progresses so the velocity is increasing ('constant acceleration'); and also the force is increasing since this will depend upon the drag forces which increase with speed. This means that the power is 'doubly increasing' leading to graph D.

A is clearly incorrect as it shows the same power irrespective of speed. For the same reason C can be eliminated as at high speeds it becomes similar to A. Graph B would result from the function P = constant x speed, which, for reasons given above, cannot be correct.

Alternatively, any candidate asking themselves "if the train goes twice as fast will its power be twice as great" should be lead towards response D as long as they know that $P = Fv$.

The statistics showed a similar spread of responses between B, C and D, with a low discrimination index. This would show that the candidates were confused about this question.

SL Q9 and HL Q6

This is a classic case of using units (and noticing the labelling on the axes!).

As far as units are concerned: *work* is *energy*; *energy* is *mass* x *velocity*^{2}; the area under the graph gives *velocity*^{2} so multiply the area under the graph by 3.0 kg. This gives answer C.

It was pleasing to see that more than half of the candidates got this correct and that it had a high discrimination index. It was disappointing to read a number of teacher comments that suggested it took too long to work out and that it was an unfamiliar situation for the students. <u>Whenever</u> a physics student is presented with a graph s/he should notice the units of its gradient and the units of a calculated area.

SL Q12 and HL Q8

Gases are close to ideal at low pressures, so B and D can be discarded. Clearly density should also be low as otherwise the particles cannot be regarded as 'point masses' so A is the only possible answer.

SL Q15 and HL Q9

Some teachers felt this question to be too 'wordy' despite the clear diagram summarising the information. There was, however, no graph showing an increasing function so if students had missed that the initial light was horizontally polarised, there was no reasonable response to choose.

When θ is either 0^0 or 90^0 no light can be transmitted so both A and D (the most popular choice!) can be eliminated. As the light between P and A will not be horizontally polarized, C cannot be correct – leaving B as the correct response.

In both SL and HL this question had a very low difficulty index with a corresponding low discrimination index, so this is clearly an area of the syllabus that needs reinforcing.

SL Q21 and HL Q13

Many teachers thought the angled rod to be an unfair distraction, trying to trick the students. It is, however, a very straightforward, if unusual, situation. The candidates who knew the fundamental pertinent principles would immediately ask themselves whether the current is perpendicular to the magnetic field. The responses were such that they did not even need to use a direction rule.

SL Q22 and HL Q14

This question also elicited many G2 comments. Some teachers thought the question was about torques and not on the syllabus. But the question asks about the force exerted <u>by</u> the rod <u>on</u> the mass.

The mass is moving at constant speed so the force provided by the rod must change to resist or overcome the weight of the mass in different positions. Eliminating A and B.

Very few candidates were able to choose the correct response, most instinctively choosing C. This option would only have been correct if weight is not considered.

SL Q26 and HL Q16

Many teachers commented that this question was unanswerable as the range of the forces was not specified. But students should realise that the gravitational force is weaker than the electrostatic force at <u>any</u> range - whether two protons are at atomic distances from each other or whether they are at planetary distances. Indeed, the students should have understood that gravity is the weakest of all the forces. So B and D are both incorrect.

The weak force is only operative at nuclear distances and unlike the electromagnetic force is inoperative at greater distances. So A is incorrect, leaving C as the correct answer.

It seemed weaker candidates had committed the order of strength of the fundamental forces to memory. The examiners accept that this is not an ideal situation and the responses have been revised for the published version.

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SL Q30 and HL Q20

The statistics suggest random guessing – especially in SL.

As the body is 'black' this must mean that the emissivity, e, is 1 and that III is correct, thus eliminating response A.

Simple application of Wien's Law and Stefan's Law show that D must be the correct response. There is no complex calculation needed – just the ability to deal with powers of ten.

HL-only questions

Q17

This question elicited a lot of comment from teachers. It was grounded in 'Nature of Science' (page 64 of the syllabus) and paper 1 will routinely contain such questions in future.

The graph shows that as a nucleus increases in size, the ratio of neutrons: protons increases. Protons repel each other and neutrons act as stabilizers holding the nucleus together with the strong force. Responses B, C and D clearly do not address this stabilizing effect of neutrons so can be safely eliminated.

Q23

This question addressed two topics (4.4 and 9.3). The envelop of the maxima gives information about diffraction, which is clearly non-negligible in this case, while the distance between the maxima (0.01) gives information about double-slit interference. Hence B.

Q24

This assesses syllabus item 9.1. It was well done by the candidates with one of the highest discrimination indices recorded.

Q26

'Work done' is by something on something (similar to forces). Students must be alerted to the importance of rigour in talking about such concepts and use the correct language. Any physicist, when asked about 'work done' would automatically wonder what is doing the work and on what!

Here it is the work done by the field on the charge. And as it is a negative charge it would naturally 'fall' in the direction shown by B and C, which therefore represent work being done by the field on the charge as required. Hence the correct response is B.

This was correctly chosen by over 60% of the candidates, but the discrimination index was zero indicating success across a full range of candidate abilities.

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Q28

It should be assumed that planetary orbits are circular unless otherwise stated.

Q29

Physics students should ask themselves how the flux linkage is changing when considering an induced emf. In this diagram the flux linkage is always zero, hence it is not changing and no emf is induced (response A).

Students should not assume every diagram will be ‘iconic’, similar to one they have come across before. They need to apply the physics principles they have learnt rather than rely on recall of familiar situations.

Q36

This relates to item 12.1 “The uncertainty principle for energy and time and position and momentum”.

SL-only questions

Q5

The examiners accept that this question would have been improved with a diagram.

The statistics suggest that many candidates incorrectly assumed that E_k gain is always equal to E_p loss.

Q6

This was well answered by most of the candidates. As the spring constant is positive the only possible correct response is C.

Q11

The mathematical modelling of an ideal gas assumes that all the particles have the same mass, whereas the velocities need to be averaged out as they are changing upon collision.

Q14

Displacement time graphs are used to show the motion of a specified particle. They are <u>not</u> a general picture of a wave! If P and Q are ducks sitting on water, then as the wave moves under them they will both move *downwards* after t = 0. The only graph that illustrates this is C.

Q20

Some teachers pointed out that the word ‘internal’ was superfluous if not incorrect. It has been omitted in the published version of the paper. There is no evidence from the statistics that this confused the candidates in any way.

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Q25

Response A may be true, but it is not a *definition* of binding energy. Response C is unfortunately a common answer given by students in paper 2. It may be a 'first step' towards grasping the concept of binding energy, but it lacks any rigour and is certainly not a definition. The only correct response is B.

Q27

This is a 'Nature of Science' question taken almost directly from item 7.3 in the syllabus. It was pleasing to see that over 50% of the candidates chose the correct 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 warmers to stimulate discussion as well as for quick tests and should never be regarded as add-ons only to be practised, a paper at a time, for the final examination session.

Multiple choice questions test a different skill to structured questions. In paper 2 students are expected to display their knowledge in a logical and communicative fashion. But multiple choice questions test quick thinking (without a calculator), insight and problem solving.

In particular the students should be adept at dealing with powers of ten quickly and efficiently.

The questions are carefully created to communicate the problem unambiguously and in as few words as possible; the words are both necessary and sufficient. After they have made their selection the candidates should make a habit to check back that they have indeed answered the question. Only then should they move on. There is evidence that many candidates are not 'back-checking' once they have made their selection. This would help with questions some teachers consider 'tricky'.

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. There is much evidence that students are not being taught the power of and necessity for units. They are there to help the student not to burden them and will often lead to the identification of the correct response.
- If two responses are logically equivalent, then they must both be wrong.
- Exaggerate a variable – this will often point the candidate in the correct direction, especially if a variable is in the denominator in one response and the numerator in another.
- A simple sketch will aid in understanding the question and often lead the candidate to the correct response.

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- Distinguish between cos, sin and tan functions – mentally making the angle 90^0 will 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 make an attempt at every item. It should be emphasised that an incorrect response does not give rise to a mark deduction.
- Graphs, force diagrams and other means of illustration are a fundamental way in which physicists seek to model and understand the world. Candidates should be encouraged to sketch their answers to problems before they plunge into calculations. There is evidence, also from the written papers and extended essays, that this is not a skill shared by many candidates.
- The question should be read carefully. 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 question 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.
- Candidates should consult the current Physics Guide during preparation for the examination, in order to clarify the requirements for examination success.
- This Guide does invite the candidates to recall certain simple facts, although most of Physics is process orientated. Such facts lend themselves to Multiple Choice questioning so the teachers should not be afraid to require their candidates to occasionally memorise information. Definitions (which are universally poorly given in written papers) are perhaps best learned and tested with simple multiple choice questions, but future MCQ papers will have about 50% AO3 questions involving higher order thinking skills.
- Candidates can expect the proportion of questions covering a particular topic to be similar to the proportion of time allocated for teaching that topic, as specified in the Physics Guide. The common knowledge that most people have about certain areas of the Guide is not always sufficient to answer questions, which are not trivial.

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Higher level and standard level paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-14	15-21	22-30	31-39	40-48	49-95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-8	9-13	14-18	19-24	25-29	30-50

General comments

This was the first examination of the new IB course in Physics. The format of Paper 2 was very different from that of previous papers. Students were clearly discomforted by the lack of choice and some appeared to have been ill-prepared for this. Nevertheless, there were some good attempts at a paper that was not particularly demanding in content but which stretched a number of candidates in terms of its time demand. There was evidence that some failed to complete the paper. In this connection it would seem reasonable for schools to feature paper-answering strategies in their teaching during the run-up to the final examination. Candidates are allowed time to read the paper before beginning the examination. They should take advantage of this to plan the order in which they will answer questions, playing to their own strengths.

The presentation of some candidates' work was poor. It is often pointless to write outside the answer box as this material may not be scanned and it is entirely possible for work to be missed by an examiner unless (i) its presence elsewhere has been flagged up in the response or (ii) it is written on an additional sheet (and preferably flagged up too). Candidates still need reminders in this respect.

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

Areas that appeared difficult included:

- Wave theory, e.g. an understanding of the implications of a displacement–distance graph for a longitudinal travelling wave
- Capacitor theory
- Diffraction and interference at multiple slits
- The interpretation of graphical material

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

- Mechanics
- Gravitation and field theory
- Electricity theory
- Nuclear stability and nuclear density

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

Q1 HL & SL

(1)(a)(i). Many good answers to this question gave excellent expression of the physics and accurate evaluations. It was very clear from these answers how the question had been tackled. A minority of solutions were however inadequate and failed to gain full credit because the substitution missed vital elements (v rather than v^2 was given) or it was not clear what was the essential expression of the conservation of energy. Some candidates have still not learnt that they must show their final answer the correct number of significant figures.

(a)(ii). Again, most gained both marks for equating the known energy to ½ mv^2 and then evaluating the answer. However, some used only the gravitational potential energy contribution to the energy and consequently arrived at a value that was too small.

(b)(i) There were many stock answers for Newton's first law that failed to score because they did not address the context of the question. Candidates did not appreciate the requirements of a question that begins "Describe". Students need to be aware of the command terms.

A wide variety of synonyms were allowed for "constant velocity" but some candidates still managed to express themselves so poorly as to lose the mark because it was not clear that the block moved at a speed that was unchanged. Students should avoid the sloppy use of the words "move" and "motion". They should learn to distinguish between acceleration and velocity in their discussion of Newton's Laws. Similarly, the term "inertia" should be avoided. The concept of energy does not feature in Newton's laws and therefore no credit was given for answers that evoked this idea.

A surprising number of SL candidates confused Newton's second and third laws. The majority of candidates talked very generally about a law without specifically mentioning the block of ice.

(b)(ii) Candidates were here required to give an account of why there was a force on the block and then the effect that this force has on the motion. Many gained the latter mark, but descriptions of the origins of the force were poor. Often there were irrelevant accounts of the energy transformations, not all of which were correct.

(c) Candidates demonstrated their continuing difficulties with the production of diagrams and sketch graphs that reflect clearly what the candidate knows about a situation in context. Many drew straight lines for the initial part of the graph for small times (over the region AB of the motion). Few used a ruler or took any care over the drawing. The second mark was awarded

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for the subsequent motion beyond C. This was much more poorly done. Some graphs showed a decreasing gradient to zero and then a negative gradient without realising the physical implications of this. Others drew gradients that increased from the straight line value usually reaching an infinite speed. This is straightforward physics at this level and should not prove so difficult for so many. Students should be encouraged to use a ruler whenever they intend a line to be straight.

(d) A good number recognised that the easy way to do this problem is to invoke the rate of change of momentum. Others took a lengthier approach via a kinematic equation and *F=ma*. Either approach scored. However, there were common failures such as the subtraction of a speed of 0.9 m s^{-1} from the 4.9 m s^{-1}. A minority had no suggested approach and simply wrote down some motion equations at random without quoting a result.

(e) It was common to see a value for either the electrical power delivered to the motor, or the total energy supplied to the motor. However, some found the following transformation to an efficiency of 55% more difficult with the wrong output energy often seen.

(f) [**HL only**] There were a pleasing number of successful attempts by candidates who were able to show convincingly that the block cannot reach C. The best approach featured a calculation of the energy dissipated in overcoming friction, but other methods including a longer calculation via the deceleration of the block and the energy available were seen. There was no credit for a bald statement of the answer, reasoning was required.

Q2 HL only

(a) It should not be too much to expect a candidate sitting a paper at this level to use a ruler to construct a line, to check with the ruler that the lines are the same length, and to ensure that the lines are directed from the stars towards the planet. Candidate who took care with the diagram generally did well gaining both marks. About 10% of the entry lost credit by drawing the direction in the wrong direction.

(b) Again, work was very mixed. Some candidate had no problems with this question and gave lucid solutions including clear accounts of both the direction of the field strength and the addition of the two vectors. There was some criticism in the G2 comments that this question fell outside the scope of the syllabus. However, it combines *one* calculation of field strength together with a problem drawn legitimately from Topic 1.3.

Q2 SL only

(a) This was a “Show that” question and as such candidates must satisfy the examiner that they understand the physics involved. Too many candidates treated this in a cavalier way with numbers appearing from nowhere but miraculously leading to the correct answer. Candidates are strongly advised to: quote any equations they are using, show the full substitution (including, in this case, the value for *G* in use, and to give an answer to more significant figures than is given in the question.

(b) The best answers here incorporated a vector diagram, for which credit was given even if there was a subsequent error.

Q3 HL & SL

(a) Candidates had a good grasp of the essentials of this straightforward question. Some credit was lost by those who forgot to include the energy required to heat the melted ice from 0 ^{o}C to its final temperature. Units were generally presented well with only a handful using the unit for specific heat capacity. Powers of ten were also well handled in presenting the final answer.

Many SL candidates did not know how to approach this question. It was common to see the use of *K* and to discover answers with no (or incorrect) units.

(b)(i) Usually was well done. (ii) A general reason for the reduction in melting time was required. This was often well expressed in terms of increased contact or surface area, but the omission of this point by a candidate denied the mark.

Q 4 HL only

It was clear from the question as a whole that candidates were unclear about the interpretation of this type of displacement – distance graph. There were many low scoring responses for a question that contained a reasonable number of easily attained marking points. The calculations were mostly of no great difficulty and candidates probably need more familiarity with the elements of this type of graph.

(a) It was very disappointing to find that comparatively few candidates could give an accurate and physically meaningful description of a longitudinal travelling wave. This should be a straight forward question that demands a standard response. Even responses that gained credit were poorly expressed with elements only partially present. Examiners needed to know what was oscillating or moving and how the direction of this motion related to the energy propagation direction.

(b)(i) Candidates who adopted an approach via the distance moved forward by the wave and the time it takes (in other words a simple definition of speed!) often found considerable success save for the occasional power of ten error (omitting the 10^{-3} for the time expressed in milliseconds). Alternative approaches via wavelength and $c=f\lambda$ gave much more difficulty and were only rarely successful.

(b)(ii) As a “show that”, examiners were looking for good detail in the explanation of the method used (again, a number of approaches were possible).

(c)(i) This caused difficulties for most candidates. Despite careful question wording, most candidates did not realise that movement in the negative direction of the graph means that the particle being represented is moving to the left.

(c)(ii) Another “show that” in which examiners were generally not convinced that students knew what they were doing. For example, candidates were frequently working out average speeds using linear kinematics forgetting that this is an oscillation with completely different characteristics of motion. Those who used the equations directly from the Data Booklet without understanding also made the mistake of forgetting to account for any phase difference involved

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in using the wrong angular dependence. There were also significant numbers of students who used degree measure rather than radian measure on their calculator in calculating the answer.

(d)(i) A Diploma candidate should be able to give an account of the origin of a standing wave succinctly and accurately. There are two elements, the interaction of two waves moving in opposite direction and a description of the interaction as a superposition or interference. Despite allowing latitude in approach (“reflected waves” etc) many were unable to answer the question and examiners also saw a large number of blank responses.

(d)(ii) Not surprisingly, this question which was more demanding also featured many blank scripts. Those who realised that they had to recognise the integer relationship between the length of the tube and the wavelength of the sound were able to predict that the third harmonic is sounded or to draw the diagram of the standing wave amplitude–distance graph in the tube.

Q 4 SL only

(a) Only about ten percent of the candidates could describe a longitudinal wave. There were ‘waves oscillating’, ‘energy parallel to motion’ and other errors. It would seem that few candidates knew that waves propagate through the oscillation of particles.

(b)(i) Most of the candidates did not understand the situation represented by the graph and simply found numbers to multiply or divide in the hope that they may give the correct answer. Those who did realise that the wave had progressed 0.3 m in 0.882 ms and who used *speed = distance/time*, often forgot the prefix in the unit ms.

(b)(ii) A number of candidates confused the *x*-axis and gave the time period as 1.6 s. But many were able to be awarded an error carried forward by applying the wave equation to their answer to the previous question. It must be stressed, though, that such credit can only be awarded if the candidate’s line of reasoning is clearly communicated. It is not the job of an examiner to second guess the candidate’s thoughts.

(c)(i) & (ii) Students found it difficult to link the graph to the physical nature of a longitudinal wave. This is clearly an area that is not well understood by students. Linking displacement–time and displacement- and –distance graphs to what is happening in both longitudinal and transverse waves is worthwhile.

Q5 HL only

(a) Candidates had simply not learnt the standard statement of escape velocity. It is linked to the energy required by an object at the surface of a planet (or other massive object) to reach infinity. It was rare to see this so expressed. There are many other statements possible, and all valid responses were allowed. However, candidates who talk about leaving an orbit or overcoming the atmospheric drag cannot expect to gain credit here.

(b) Only a handful of candidates could attempt this question with facility. The essential steps are: equate the total energy at the surface with the total energy at the maximum height, express the kinetic energy at the surface in terms of escape speed using the data and the escape

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velocity equation in the Data Booklet, and then subtract *R* to allow for the height change from the surface rather than from the centre of the planet. Correct solutions were extremely rare.

(c) This is an old and intriguing chestnut: the total energy of an orbiting satellite suffering frictional drag decreases its orbital radius and as a consequence speeds up. Many thought that loss of total energy meant only loss of kinetic energy and therefore a smaller speed.

Q5 SL only

A number of candidates disregarded units throughout this question. Units (with correct powers of ten) must be given for all answers to have physical credibility.

(a) Most candidates knew that an ideal voltmeter had infinite resistance, although many thought its resistance was zero.

(b)(i) & (ii) A very standard graph that students should have seen as part of their studies (*Subject Guide:* topic 5.3.9). Only a minority, though, were able to use it to give the emf and internal resistance of the cell.

(c) It must be stressed that the candidates need to show evidence that they are using the correct equations and have substituted the correct numbers. Copying answers directly from a calculator without clear indication of the origin of the input does not receive credit.

(d) Many left this blank or simply guessed the direction.

Q6 HL only

(a) Although this appears to be a classic Kirchhoff-style calculation it can be answered much more simply. As in previous examinations, there was evidence that IB students have a poor grasp of electricity theory and fail to make essential connections between key concepts. The fact that the ammeter reads zero should have told most candidates straight away that the 3 ohm resistor loop is irrelevant and therefore the pd across the 4 ohm resistor must be equal to the emf of the unknown cell: a straightforward two-line answer. However, it was pleasing to see that many candidates scored the first mark for a reasonable stab at a Kirchhoff loop. However, some could not go on to solve the problem completely. Students should look at the (simple) circuit and redraw it, or think how it might be simplified.

(b) (i) A surprisingly large number were able to show that $V=BvL$ in the situation presented. The best solutions were either from equating magnetic and electric fields, or from equating the work done (*force* x *distance*) and the product of pd and charge. Some solutions via a rate of change of flux were allowed, but these were generally poorly explained.

(b) (ii) The majority of candidates were able to assign the accumulation to the bottom plate with only a few assigning it to the top plate. There was a significant number who felt that it was to the right-hand side of the diagram and clearly had not thought through or understood the situation.

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Q6 SL only

(a) Very few candidates were able to answer this question with confidence. Many subtracted 8.398 from 8.450 but got no further. The question says that these numbers refer to the binding energy **per nucleon** so the result of the subtraction needs to be multiplied by the number of nucleons.

(b) This was mostly done correctly.

(c) The new syllabus requires the students to consider the philosophical and contextual background of the concepts they are exploring. Teachers are strongly urged to integrate the *Nature of Science* into their teaching. Ideas were introduced into physics in order to make sense of an otherwise confusing world. Students need not only to know the facts, but also to know the purpose of the facts.

Many candidates failed to score at all on this question

Q7 HL only

This was the first test of this new material in the Guide. Although there were plenty of high-scoring answers, in general, weaker candidates could not answer the descriptive or more difficult calculation material at the end of the question.

(a) The vast majority had at least a reasonable idea of the general shape of the discharge curve. Fine detail was not so well represented however. The graph should start at 12 V and cross the pre-drawn curve at 6 V and then ideally reach a value of about 0.2 V at 100 s. As is so often the case, candidates do not look critically at the evidence in front of them and examiners saw: curves too high at the crossing point, curves cutting the time axis, and inaccuracy in the starting position at t = 0. A significant minority drew a horizontal line at 12 V implying that no changes were occurring.

(b)(i) Examiners required a statement of the meaning of time constant in terms of the time taken for the charge/pd/current across the capacitor or in the circuit to fall to $\frac{1}{e}$ of its initial value – or the appropriate converse for charging. To describe the time constant as RC will not do as this is simply a direct quotation from the Data Booklet.

(b)(ii) This was a straightforward application of $\tau=RC$ for one mark. Poor rounds (to 4.8 MΩ rather than 4.9 MΩ) were condoned on this occasion (and were common) but misuses of powers of ten were common.

(c)(i) and (ii) Many erroneous answers were seen. No reasons were required even though they were often given. Most candidates stated that the potential difference across the capacitor falls, and that the charge remains the same, thus treating the situation as one in which the cell is still connected to the capacitor. Examiners suspected that students had been taught this particular case and had failed to work through the physics for the different situation.

(d)(i) A pleasing number recognised that the value of the capacitance doubles when the permittivity doubles and were able to go on to calculate the new stored energy as a result.

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(d)(ii) A clear description of the destination of the energy removed from the capacitor was beyond many when all that was actually required was to say that it was transferred to the resistor or that it was eventually dissipated in the surroundings.

Q8 HL only

(a) Attempts to show that lepton number is conserved in the quoted equation were only successful in about half of the scripts. The main failure was to make it clear that the lepton number of *both* quarks is 0; usually candidates focussed their attention and comment on only the d quark. So equations were written typically as $0 \rightarrow 1 + -1$ with no clear indication at all that the u quark was even present in the equation.

(b)(i) As in previous years, candidates had not memorised the definition of binding energy and could not reconstruct a definition from their understanding of the concept.

(ii) Determinations of the energy released in the decay were generally good although perhaps 30% of the candidature could only evaluate the difference between the binding energy *per nucleon* and could not get further towards the binding energy change for the whole nucleus.

(c) This was a question that referenced the nature of science areas of the syllabus. Although many appropriate responses were seen, it was unusual for candidates to obtain more than 2 of the 3 available marks. There were quite a number of blank responses for this question suggesting that candidates were not well prepared for answering this open-ended type of discussion.

Q9 HL & Q7 SL

(a) As in other parts of the paper this was a “show that” and there was a requirement for the examiner to be completely convinced about the origins of the physics and the evaluation of the result. For those who relied on making the calculation, 4 significant figures were required. Those who preferred not to use their calculator had to show a complete algebraic equation and a complete substitution with the requisite factors of 4π shown. As there is considerable ambiguity in the meaning of “area” in this question (whether circle or sphere), achieving clarity here was essential for full credit. Generally, candidates should have described their working in greater depth including a quotation of the equation, the value substitution *in full* and the answer quoted to a suitable number of digits beyond those given in the question.

(b) Considerable latitude was allowed in this part. The recognition that 980 W m^{-2} of power falls on the Earth was commonly seen and then almost all students could spot that this was four times the quoted answer. Examiners did not on this occasion require a statement of the 4π and π cancellation which is the actual physics on display – this was fortunate as most candidates did not provide it. Only a handful gave good geometric accounts of the origin of the factor 4.

(c) This was very disappointing in that the equation for this part is directly quoted in the Data Booklet yet a large number of candidates could not access the mark. Many scored 0 despite writing down the Data Booklet equation. Equations that are direct quotes rarely score credit in IB physics assessments although it remains important to quote them as the starting point for the work.

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(d) Too often candidates stated that the greenhouse gases “trap the heat” and left their description at that. It was comparatively rare to see a good well-written answer that suggested the actual wavelength of the radiation concerned, its absorption (or a mechanism for its absorption) by greenhouse gases *in the atmosphere* and the description of the re-radiation of the energy *in all directions* so that the equilibrium temperature of Earth is increased.

Q10 HL only

(a) There were many good answers to this first part. Most recognised that constructive interference was the mechanism at work with somewhat fewer discussing good links between the amplitude and intensity and hence deducing the factor of 16 from an amplitude four times greater than the original.

(b) (i) and (ii) Candidates found these questions very demanding. Most were confused as to the true significance of the diffraction envelope (with its first minimum at 0.43 rad) and the first interference peak (maximum at 0.125 rad) and so were using both inappropriate angles and equations. This is an area of work new to the *Guide* and evidently needs to be addressed more carefully by candidates.

(c) (i) Candidates often knew that the intensity of the principal maxima increases and that the principal maxima become sharper but they did not have the vocabulary to make it completely clear that it was the principal maxima that they were discussing. Almost all talked simply about changes to the “maxima”. Changes to the secondary maxima were rare, so again this is work with which candidates should be more familiar.

(ii) The calculation of the minimum number of slits was well done by many and has obviously been well practised. The principal error was to omit the factor of 2 because the second-order lines were under consideration.

Q11 HL only

(a)(i) Essential requirements for an answer were a clear and competent transformation of the MeV values into joule and an accurate substitution of all values (including the physical constants) in a coherent expression. An alternative for some credit was to see the final value calculated to a convincing number of significant figures evaluated on a calculator. Elements of both these were often missing.

(a)(ii) The determination of the density of nuclear material should have been straightforward but the common omissions of 3 in $\frac{4}{3}\pi r^3$ and confusions of powers of ten meant that only perhaps half of the cohort scored full marks.

(b) In only the first part of the question was a full explanation required for the changes when an isotope is used. This was in the first part (distance of closest approach). Many simply said there was “no change” and did not amplify this answer. Examiners were lenient and accepted as an answer many forms of words including “because there is the same charge/same number of protons/neutrons have no charge” etc. However, only a statement of “the same” or words to that effect was required for the second part: the estimate of nuclear density.

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(c) This was a difficult closing question and it was good to see this well answered by perhaps half of the candidates. Many used a value for Δx of 7×10^{-15} m but values of half and double this were accepted as equally good estimates of the nuclear radius. Many were then able to operate with the uncertainty in the momentum obtaining accurate evaluated values. However, it was at this point that things went astray. Candidates either offered their answer in joule (MeV was demanded) or could not cope with the powers of ten in the calculation.

Recommendations and guidance for the teaching of future candidates

It is recommended that candidates should be taught:

- to structure their calculations giving full explanation of the steps undertaken
- to have regard to the meaning of command words in questions
- to present material, both written and drawn, in a coherent and logical way
- strategies for answering an examination where there is no element of choice
- to offer answers that lie firmly within the context of the question as set
- to learn to reproduce standard statements and descriptions of phenomena, eg the meaning of binding energy and escape speed and the nature of a longitudinal travelling wave

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Higher level and standard level paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-19	20-23	24-27	28-31	32-45

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-8	9-13	14-16	17-19	20-22	23-35

General comments

The paper was based on new Physics guide. Section A was prepared for summative assessment, mainly of Topic 1 Measurement and uncertainties. The contexts for the assessment were selected appropriately; candidates proved that context of investigation of rod oscillation and context of refractive index measurement with use of microscope were both well understood.

Options in Section B were well balanced. In each of the options were questions measuring the level of the knowledge, understanding, skills and other of the assessment objectives 1,2 and 3 required by the syllabus. In the line of the Physics guide, the paper presupposed also knowledge on core material.

Also the questions from section B were set to well selected contexts and applications. The candidates proved that they had enough time for work. Discrimination of the paper was at the appropriate level, difficulty of all of the options was almost the same. Among answers we can see many examples of good understanding in each of the questions. Almost all candidates answered all questions from section A and all questions from one option selected. The vast majority of candidates kept responses in the answer boxes provided and if used extension sheets they referred this within the answer box. Handwriting seems to be at the same level as earlier sessions, the answers were legible.

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

Some candidates failed in presenting their working in logical and clear manner. Some did not follow the key phrases and so do not read and answer the questions accurately. Generally, phrases like define, show that, compare, and ‘distinguish between’ were followed by candidates better than previous sessions.

Difficulties related to the syllabus details:

- error bars (1.2);
- explaining how systematic errors are reduced (1.2);
- use direct proportion (mathematical requirement, p. 22);
- analyse and evaluate hypothesis (assessment objectives, p. 18);
- forces on a charge (A.1);
- spacetime diagrams (A.3);
- solving problems using rotational quantities (B.1);
- explaining situations involving Bernoulli effect (B.3);
- diverging mirror, ray diagrams (C.1);
- solving problems involving the thin lens equation (C.1);
- simple optical astronomical refracting telescope (C.2);
- nuclear magnetic resonance (C.4).

Other difficulties:

- arithmetic and algebraic mistakes, calculator mistakes;
- wrong units (e.g. meter for index of refraction; not penalised in most of the questions);
- power of ten (POT) mistakes in calculations; sometimes leading to unrealistic results, e.g. star in the distance of few kilometres;
- layout of working in numerical questions, it is sometimes hard to see where a mistake occurred and award partial or ECF marks;
- sequencing the presentation of facts to support an explanation and description;
- some candidates read questions superficially and, wrote correct statements not answering the question.

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

The greater majority of candidates have clearly seen the new Physics Guide and their study was based on this document.

The well prepared candidates could analyse the situations, present working in logical manner and use proper terminology, physical quantities and units. Most candidates presented an ability to analyse situations in various contexts, to read and understand questions. They demonstrated understanding of facts and concepts and were able to use them with proper terminology. Most candidates proved the ability to clearly present well known facts in words and sentences.

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

Section A Both questions were accessible to well-prepared candidates. However, many candidates failed in different parts of the questions.

Q1

(a) Quite unpredictably high numbers of candidates drew a straight line as a best fit line, showing that they do not understand the basic term "best fit line".

(b) This question discriminated well between candidates. Only a few candidates failed to read the uncertainty correctly from the graph or used the value of time instead of displacement.

(c) This was the most problematic question for the candidates, many even generally good candidates failed in (i) and in (ii); the (ii) discriminated well between the best and average prepared candidates. In (i) only about half of the students could draw the point correctly, (ii) very poorly answered as students failed to recognise the difference between linear and proportional.

Q2

(a) Quite high number of candidates answered with 3 significant numbers in (i), but part(ii) on uncertainty propagation was answered well.

(b) and (c) The name of the error was generally well stated, effect of the error on the calculated value in (ii) was well identified by well and average prepared candidates and effect of replacement of the glass slide was well explained only by the best candidates. A highly discriminating question. Some students failed in (c) because of lack of precision, referring to the material of the slide and not referring to the effect on the calculated value. Some candidates had difficulty in applying this topic in different contexts.

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Section B

Option A Relativity

3. Good question on the basic terms and concepts of special relativity. Well done by variety of candidates, even by some weak candidates.

4. Nice question measuring the level of knowledge in relativity of forces on charge and current and also the ability to construct a detailed explanation of complex phenomena. Majority of candidates gained few marks, only the best one gained full marks. Many students identified that there would be an electrostatic force and magnetic force but failed to mention whether it would attractive or repulsive and to justify their causes.

5. Standard question on relativity generally well answered. Weak students made mistakes in the reference frames, some of them made algebraic and/or arithmetic mistakes.

6. Question on spacetime diagrams proved some difficulty for students not used to working with such diagrams. Easiest was part (b) and most difficult c (i). We have seen many excellent answers here; we recommend using similar questions for future candidates.

7.(HL only) This question detected an inability to effectively use appropriate terminology by weaker and averagely prepared candidates and solve complex unfamiliar problems.

Option B Engineering physics

8.(SL 7) Rigid body

(a) Most of the candidates understand the concept of torque and many of them were also able to present the concept adequately. Some students provided poor answers and just repeated the question.

(b) (i) Not easy complex problem measuring the level of each, understanding, subject knowledge, application and problem solving ability. Many candidates gained one or two marks for correct recognition of knowledge to use, but better candidates were also able to apply Newton's second law for angular motion. A small portion of the candidates used energy conservation, generally well, with good results.

Very few SL students managed to obtain the required result. The most common mistake was to confuse the angle of the slope with the angle in the torque formula. Very few identified that they had to use both Newton’s law for linear motion and for rotational motion. The answers were often difficult to read as they had no logical structure.

(ii) After complex problem in (i) many candidates failed in application of uniformly accelerated motion formula for distance travelled. However average and better candidates had no difficulty here.

(c), (d) The effect of replacements of the solid cylinder with ice block and hollow cylinder were well outlined only by better candidates and many of them constructed proper detailed explanations.

SL students too often repeated the question in (c) without providing an argument to support their reasoning. Many answers included a discussion of the moment of inertia of the ice cube and only few SL students realised that the moment of inertia would increase and fewer then deduced that the acceleration would decrease

9.(SL 8) Thermodynamics

Standard question with variety of concepts of thermodynamics, prepared candidates proved no serious difficulties here.

10.(HL only) Fluid dynamics

Only better candidates explained well the change of the pressure in (b). The vast majority of candidates distinguished between laminar and turbulent flow in (c)

11.(HL only) Forced vibrations

Q factor of damping and phase shift in the state of resonance and forced vibration out of resonance were well understood and applied only by the candidates who have studied this part of the syllabus in detail.

Option C Imaging

12.(SL 9) Ray diagram for a spherical mirrors proved difficulty, many candidates failed here. The comparison of the parabolic and spherical mirrors was outlined well by majority of the candidates.

13.(SL 10) The application of knowledge of lenses, microscopes and telescopes was successful for the best candidates, many weak candidates gained only few marks here.

14. (SL 11) Many candidates were not familiar with concepts of graded-index fibres and waveguide dispersion. The rest provided detailed explanations here.

Many SL students drew straight lines in (a) and in (b) many SL students confused material and waveguide dispersion. Very few SL students provided answers with the level of sophistication expected.

15.(HL only) Utilisation of information about absorption coefficient for evaluation of the effect of aluminium sheet in medical imaging was well done by the better candidates. Many weaker candidates failed in applying the proper formula, some failed in reading from the graph provided.

16.(HL only) The great majority of the candidates compared MRI and X-ray imaging in (a). In (b) only the best candidates logically and concisely explained function of the gradient field, but many candidates gained at least partial marks here.

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Option D Astrophysics

Most popular option this year

17. (SL 12) (a) Generally well answered

(b) and (c) Nice question on unit transformation. Generally, well answered but quite often after arithmetic or algebraic mistake results of a few kilometres, or even distances appropriate to atomic physics were presented as a distance of the star from the Earth.

18.(SL 13) Very well answered question. The hardest part (e), where weaker candidates failed in making appropriate predictions of complex phenomena. Many students failed to realise that a large part of the mass would be ejected during the planetary nebula stage. Many answers, especially in SL, were more a collections of statements that had little logical connections.

Very few SL students seem to know how to calculate the surface area of a sphere.

19. (SL 14) A question with good discrimination between candidates.

(a) Only better candidates outlined cosmological redshift in (i) and the ratio of the size of the universe when the light was emitted to the present size in (i).

(b) The majority of the candidates constructed explanations and better candidates provided detailed explanations of this complex problem.

20. (HL only) Great variety of answers, from little knowledge presented to comprehensive knowledge in the topic of stellar processes.

21.(HL only) Easy question on cosmology with some inconsistencies presented by weaker candidates.

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Recommendations and guidance for the teaching of future candidates

Based on the evidence gathered from the responses this session we can offer following recommendations: that candidates

Candidates score better in Paper 3, if they:

- are informed about aims, objectives and syllabus details at early stage of IBD study and at the final stages of preparing checks understanding of basic terms and definitions mentioned in Physics Guide;
- are informed about standard command terms and the terms are often used in communication between teacher and student during whole learning/teaching process; this seems to be equally important in teaching students who are working in mother language or in second language;
- study the option before revision of core physics, to see connections among topics;
- use Data Booklet when solving multistep, complex problems;
- try not only understand and apply, but also remember formulations of definitions, especially of physical quantities used only in options;
- are trained to express their ideas in written form, in logical manner, in proper layout, showing each step.
- are encouraged to write some words explaining their working also in calculations, derivations and other use of formulas; especially in not fully correct answers or alternative answers this can be helpful and candidates can gain some marks for partly correct working; also candidates can find their own mistake in derivation, or calculation and can amend their answer;
- do not neglect units, sporadically we can see mistakes, e.g. well calculated index or refraction and distance unit used; or nonsense answer given as a result of POT mistake
- are encouraged to be careful with the difference between “linearly dependent” and “directly proportional”;

Candidates must be reminded that every word must be readable, 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 in the box or on the additional sheet.

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

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