May 2015 subject reports

Physics Timezone 1

To protect the integrity of the examinations, increasing use is being made of timezone 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 2015 examination session the IB has produced timezone variants of Physics HL and SL papers 1, 2 and 3.

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0–15	16–28	29–39	40–49	50–60	61–70	71–100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0–14	15–25	26–35	36–45	46–57	58–67	68–100

Higher and standard level internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0–8	9–16	17–22	23–27	28–33	34–38	39–48

The range and suitability of the work submitted

The scope and range of practical work was impressive. Most schools had a comprehensive practical program and teachers were assessing appropriate high school level investigations. The quality of most candidate's work was good, and even schools where the candidates were academically weak still demonstrated enthusiasm and determinism with their investigations. The majority of candidate reports were word-processed and graphs were drawn using graphing programs. There was a good use of ICT in various investigations. Overall, the majority of schools are doing an exemplary job of implementing a practical programme.

Candidate performance against each criterion

Design (D)

Most teacher's prompts were in line for appropriate Design investigations. There were many examples of tried and true prompts, like the cantilever and ball bounce investigations. There were also genuinely new investigations where the teacher's prompt was non-directive, such as investigate something you like. Weakness arrived only in a few cases where quantities could not be quantified, like bouncing a ball off different surfaces (where a histogram was used instead of a linear graph) or where the teacher assessed Design for a well-established investigation, like Boyle's law or the speed of sound using a resonant tube filled with water.

Data Collection and Presentation (DCP)

As expected, candidates often earn high marks under the DCP criterion. Raw data always has uncertainty, if no other value than least count, and candidates should easily address expectation. Moderators are looking for a brief statement to why the candidate gives a particular value of uncertainty, and this holds for both raw and processed data. When assessing DCP candidates are expected to have produced graphs. Graphs allow the detection of outliers and systematic errors in the data trend line. There were some cases where graphs would have been relevant but candidates just made calculations. There were a few cases of graphs without error bars and without the determination of the gradient uncertainty. Again, candidates easily achieve these if they realize the appreciation of uncertainties is expected. Examples like this cannot earn complete for DCP aspect 3. Scatter graphs should graph best-fit lines (linear or curved) and not point-to-point lines. Finally, there were a few cases of scatter graphs that clearly described curves but candidates forced a linear line. Teachers should guide candidates away from this.

Conclusion and Evaluation (CE)

This continues to be the most difficult criterion for candidates. Under CE aspect 1, candidates need to think beyond the given data in order to provide a justification based on a reasonable interpretation of the data. Such insight might look at the extremes of the data range, the origin of the graph, the *y*-intercept, for some physical meaning. Candidates might even give the overall relationship some physical interpretation (perhaps a hypothesis). If candidates perform a standard and well-established physics lab, and CE is assessed, then it is unlikely that they can really come up with weaknesses or improvements. CE is also best assessed when candidates have designed and performed the investigation themselves.

Recommendations for the teaching of future candidates

The November 2015 examination session will be the last session with the current IA criteria. The May 2016 examination session will include new internal assessment criteria and expectations. The current candidate knowledge of design, data collection and analysis, graphing and error propagation, and conclusion and evaluation will be of great help with the new IA. It is recommended that throughout the course the teacher can enrich candidate's experience by suggesting possible extensions to this or that classroom investigation. Doing so can help encourage candidates to think about their own IA. It is also recommended that teachers clarify and enforce the idea of academic honesty. The Group 4 Project will be a good place to teach research skills as well.

Further comments

The current IA system has become all too familiar to teachers, and many are cutting corners with just two investigations that assess each criterion. The time has come for a new approach to IA, and in May 2016 new criteria will be used. Teachers and candidates need to plan well ahead for the expectations and requirements of the new IA.

There were some alarming cases of candidates earning zero points under all three IA criteria. Even when this is the case, teachers must submit the work that earned zeros. There was a case where the teacher awarded zero under Design but was moderated up.

Higher and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0–10	11–13	14–16	17–20	21–25	26–29	30–40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0–7	8–9	10–11	12–14	15–17	18–20	21–30

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 is 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.

Only a small percentage of the total number of teachers or the total number of centres taking the examination returned G2's. For SL there were 61 responses from 511 centres and for HL there were 36 responses from 317 centres. While we would like to thank those who took the trouble to provide G2 feedback, we would urge all centres to contribute; comments from teachers are carefully considered and inform the process of setting realistic and fair grade boundaries given the nature of the paper.

The replies received indicated that the May 2015 papers were generally well received, with many of the G2's received containing favourable comments. 83% of the HL respondents and 90% of the SL respondents felt that the paper was of an appropriate difficulty. Similar percentages felt that the paper was in line with last year's paper. The mean mark for the HL paper was 0.5 marks higher than last year, with the SL being 1.5 marks lower.

With few exceptions, teachers thought that the presentation of the papers and the clarity of the wording were either satisfactory or good.

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 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.

Higher level paper one item analysis

Number of candidates: 3653

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	388	721	489	2049	6	56.09	0.52
2	1768	861	697	325	2	48.40	0.29
3	130	393	2772	353	5	75.88	0.33
4	1534	498	1350	263	8	36.96	0.35
5	213	457	2635	344	4	72.13	0.34
6	63	3324	212	52	2	90.99	0.17
7	249	1450	1262	685	7	39.69	0.47
8	765	311	842	1731	4	47.39	0.45
9	2697	676	107	170	3	73.83	0.35
10	204	1811	163	1470	5	49.58	0.23
11	1270	722	1433	213	15	34.77	0.31
12	1650	241	227	1525	10	45.17	0.59
13	731	2401	33	484	4	65.73	0.41
14	1906	744	721	273	9	52.18	0.50
15	511	603	2074	457	8	56.78	0.51
16	1132	1813	378	323	7	49.63	0.47
17	386	1553	731	973	10	26.64	0.41
18	1433	548	526	1142	4	39.23	0.29

19	1272	459	1313	599	10	35.94	0.51
20	458	356	1136	1697	6	46.45	0.38
21	83	883	1756	927	4	48.07	0.54
22	50	790	404	2408	1	65.92	0.29
23	1310	1222	450	666	5	35.86	0.47
24	1660	1048	235	707	3	45.44	0.58
25	173	1671	1680	125	4	45.99	0.45
26	1005	746	394	1500	8	27.51	0.47
27	437	1624	1123	464	5	44.46	0.38
28	1737	96	93	1722	5	47.14	0.28
29	110	293	1327	1917	6	8.02	-0.01
30	884	1317	112	1338	2	36.63	0.49
31	523	1852	627	635	16	50.70	0.59
32	650	1794	394	804	11	49.11	0.41
33	693	1211	1107	622	20	17.03	0.27
34	496	640	1470	1029	18	40.24	0.49
35	392	498	521	2228	14	60.99	0.33
36	2261	121	684	576	11	61.89	0.36
37	107	3293	159	82	12	90.15	0.15
38	1250	331	1918	130	24	52.50	0.45
39	203	200	2724	505	21	74.57	0.34
40	1194	1236	463	727	33	32.69	0.42

Standard level paper one item analysis

Number of candidates: 6063

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	923	1283	1222	2611	24	43.06	0.51
2	643	3876	353	1166	25	63.93	0.40
3	2887	197	2899	74	6	47.62	0.55
4	191	832	3795	1238	7	62.59	0.37
5	300	879	4058	813	13	66.93	0.41
6	607	2081	350	3011	14	34.32	0.27
7	2639	872	2018	518	16	33.28	0.28
8	476	809	4123	647	8	68.00	0.31
9	2370	1198	869	1616	10	26.65	0.36
10	754	2517	2231	555	6	41.51	0.42

11	446	1632	2340	1635	10	26.92	0.24
12	2697	1264	890	1182	30	44.48	0.46
13	470	2534	544	2502	13	41.79	0.25
14	2055	1531	2230	227	20	33.89	0.18
15	1825	548	634	3044	12	30.10	0.44
16	1982	1377	1280	1420	4	32.69	0.27
17	2524	874	1662	992	11	27.41	0.40
18	2859	428	1726	1037	13	47.15	0.60
19	129	1639	808	3478	9	57.36	0.34
20	1404	2203	1099	1332	25	23.16	0.31
21	2352	1335	842	1519	15	25.05	0.36
22	532	1099	647	3778	7	62.31	0.50
23	732	2620	1774	913	24	43.21	0.31
24	3107	232	218	2488	18	41.04	0.31
25	3368	1842	632	201	20	55.55	0.41
26	766	1338	1872	2057	30	30.88	0.42
27	846	2589	2231	369	28	42.70	0.28
28	796	941	1026	3279	21	54.08	0.33
29	826	1904	2117	1157	59	31.40	0.29
30	338	5125	344	216	40	84.53	0.23

Comments on the analysis

Difficulty

The difficulty index varies from about 8% in HL and 23% in SL (relatively “difficult” questions) to about 90% in HL and 84% in SL (relatively “easy” questions). The papers gave an adequate spread of marks while allowing all candidates to gain credit. The 8% question at HL (question 29) was unusual – 36 of the questions had an index over 25%.

Discrimination

All questions except HL Q29 had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. This was achieved in the majority of questions. However, a low discrimination index may not result from an unreliable question. It could indicate a common misconception amongst candidates or a question with a high difficulty index.

“Blank” response

In both papers, there were a number of blank responses throughout the test with a slight increase towards the end. 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, 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

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, ie those that illustrate a particular issue or drew comment on the G2's.

Higher level and standard level common questions

SL Q7 and HL Q4

This is a very common mistake. The most popular choice for both HL and SL candidates was A, indicating that the vector nature of momentum is not generally appreciated.

SL Q11 and HL Q7

It is strange that so many candidates missed the obvious. Clearly any particular molecule in a gas changes its kinetic energy as it undergoes collisions. C was the most popular response for the SL candidates, indicating perhaps that they had not considered B and were working by elimination.

SL Q13 and HL Q10

D was a popular option. But as damping is increased and friction is introduced into the system so the time per oscillation will increase. Hence B.

SLQ15 and HLQ12

This generated much discussion amongst the teachers. We must remind them, however, that the best response is required. Many candidates, especially in SL, opted for D. This indicated that they understood that interference was involved but had not processed the numerical data to determine whether it was constructive or destructive interference. The path difference is 6 cm, which is clearly not a whole number of wavelengths. Hence D must be incorrect.

Examiners are not trying to trick candidates, but they do expect that all the information in the question will be read.

SL Q17 and HL Q19

A was a very popular option for both SL and HL candidates. The emf of a cell is defined as the energy per coulomb of charge that is transferred into electrical energy by the battery. Some of this energy will be dissipated as heat in the internal resistance of the cell, while the rest will be transferred to an external circuit. So A, B and D must all be incorrect.

SL Q20 and HL Q23

The statistics show that many candidates do not fully understand that field lines show the "direction of travel" of a positive charge. Instead they thought that a negative charge would be attracted *directly* to a positive charge. It is worth reinforcing with candidates that masses/charges/monopoles respond to the local direction of field and not from the position of the distant object that gives rise to the field.

SL Q24 and HL Q28

Questions on binding energy per nucleon are common in paper 2 and the candidates frequently appeared to be confused. The binding energy per nucleon curve has a negative gradient in the fission area to the right of Ni/Fe. This means that when fission occurs the reagent X will have a higher binding energy per nucleon than the products Y and Z.

Candidates should distinguish between the binding energy per nucleon, the mass deficit and the nuclear binding energy.

Higher level questions

Q17

Most candidates opted for B, ignoring the reduction in intensity caused by the passage of the light through the first polarizer. Beware of the automatic application of an equation.

Q20

Flux density and flux linkage are two very different things, having different units. Faraday's Law relates to the rate of change of flux linkage.

These concepts need careful teaching and reinforcement – there is evidence from a number of sources that candidates find them difficult.

Q25

The candidates showed that they were confusing potential and field strength. If the potential is the same for both planets then $-\frac{Gm}{r}$ will be the same for both, leading to C (not B).

Q26

Crossing equipotentials at 90° does not involve any energy change. Hence the "*y*-journey" is irrelevant to the answer, which can only be A.

Q29

The statistics show that most candidates were guessing between incorrect answers. This question is frequently asked in paper 2 and it elicits many comments from teachers (as it did here) and confusion from candidates.

Intensity refers to the energy carried by the wave per unit area per unit time. Its units are Wm^{-2}. So if light maintains the same intensity but changes from red to blue then the number of photons emitted per second will decrease (as each one is more energetic). So the answer can only be B.

Teachers should be absolutely clear with their candidates that the intensity of a wave and the number of photons per second are two very different things.

Q30

Too many candidates chose B. Perhaps their minds were still on question 29, but it is more likely that they just read the key words "wave" and "electron" and jumped to the wrong conclusion.

Multiple choice questions are often obvious – but only after careful reading and visualisation.

Q33

Candidates should know that the continuous nature of the positron energy spectrum must imply that the energy spectrum for neutrinos will also be continuous. The statistics show that there was much confusion on this point.

Q40

The multipliers p/k/n, etc, are written in the data booklet. The number of candidates who responded with B showed that they perhaps did not understand the meaning of "Pico".

Standard level questions

Q1

Units are fundamental to physics and candidates should take every opportunity throughout their course to manipulate them and use them to identify errors. The statistics showed that these candidates found this very easy manipulation rather difficult.

Q3

A candidate completing a physics course at this level should know the difference between acceleration and velocity. Here the most popular option was C which may indicate that there is confusion between these two concepts in many candidates' minds.

Q9

The mole is the amount of a substance that has a certain number of identical "things" in it. So you can have a mole of peanuts. So only B and D could possibly be correct. But we can have a mole of water molecules. Each molecule contains 3 nuclei, but that is irrelevant – the particle we are counting is the molecule. So B cannot be correct, leaving D as the only possible answer.

Q10

Temperature is a measure of the average kinetic energy of the molecules. So if the vapour and the liquid have the same temperature (as we are told in the stem) then there can be no change in average kinetic energy of the molecules. So C must be incorrect. The fact that so many candidates chose C reveals a basic misconception that needs to be carefully addressed.

Q21

In order for a magnetic field to exert a force on a moving charge the charge must be moving at an angle to the field. In this question the stem states that the charged particle is moving in the direction of the magnetic field. So A (the most popular option) must be incorrect.

Q27

Candidates correctly identified A as a distractor (and D as nonsense), but then chose B and C in almost equal numbers. It is true that both the distance of the Sun to a point, and also the amount of atmosphere that the Sun's rays have to pass through, will both affect the intensity of radiation.

But the difference in the distance from the Sun to P and to Q is negligible, whereas the difference in the path length through the atmosphere is significant. Hence the best answer must be B.

Q28

Tidal generators are not able to respond to a sudden increase in demand when the tide is turning. So D is the correct answer.

Q29

Candidates should look carefully at which way ratios are presented. In most cases it should be intuitively easy to say whether the answer is greater than or less than one.

In this case X is cooler than Y but emitting the same power. So it must be larger. Hence C and D must both be incorrect. Everything else being equal, Wien's displacement law would suggest that the doubling of the temperature would result in a 16-fold difference in intensity. But the intensity is also proportional to the area and we are being asked about the ratio of the radii. So the answer cannot be A and must be B.

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 as 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 to be practised, a paper at a time, solely for the final examination session.

Multiple choice questions test a different skill to structured questions. In paper 2 candidates 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.

Teachers frequently comment on unfair "tricky" questions, but the physical world has a history of tricking scientists into false conclusions. In order not to be "tricked", candidates must read the question very carefully to visualise the situation. 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.

There is no single most successful strategy with MCQs, so flexibility of thinking is needed. Candidates 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 candidates are not being taught the power and necessity of units. They are there to help the candidate 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.
- Draw the situation while reading the stem. A simple sketch will aid in understanding the stem and often lead the candidate to the correct response. This is particularly important for those candidates with weak language skills.
- Distinguish between cos and sin functions – mentally making the angle 90˚ will show which is correct.
- Use proportion: new quantity = old quantity × a fraction, where the fraction depends

upon the variables that have changed.

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

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

The Guide does invite the candidates to recall certain simple facts, although most of physics is process 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.

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. The common knowledge that most people have about certain areas of the Guide is not always sufficient to answer questions, which are not trivial.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0–11	12–22	23–33	34–42	43–51	52–60	61–95

General comments

At HL, only 40 centres out of 317 provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage; 90% of centres thought the paper was of appropriate difficulty, the remaining 10% of centres thought it was too difficult. 45% of centres thought the paper was of similar difficulty to last year, 20% thought it more difficult and 20% thought it easier. 70% of centres thought the clarity of the wording was good to excellent, 20% thought it fair and 10% thought it poor or very poor. 80% of centres thought that the presentation of the paper was good to excellent, 17.5% thought it fair and 2.5% thought it very poor.

It was noticeable again in this session that candidates' use of correct key terms was varied with many vague answers given to descriptive questions. Examiners felt that often candidates had an idea of the answers but didn't express themselves in a sufficiently precise way. Definitions were generally poorly stated with examples in this paper including heat capacity, simple harmonic motion and quantum efficiency.

Too many candidates set out calculations in a haphazard way which hampered their ability to work logically to a final answer, however, this year there was a noticeable increase in the number of candidates who showed their workings.

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

- Recalling standard definitions.
- Discussing absolute and percentage uncertainties.
- The details of nuclear fuel enrichment.
- Describing processes using the first law of thermodynamics.
- Describing electromagnetic induction.
- The concepts of phase and phase difference.
- Interpreting a decay series.

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

- Plotting data points and error bars.
- Calculations involving combining percentage uncertainties.
- Drawing and labelling the forces in a free-body diagram.
- Resolving forces into components.
- Calculating currents, p.d.s and resistances.
- Describing the enhanced greenhouse effect and discussing the mechanism by which greenhouse gases contribute to global warming.
- Describing energy changes during a change of state.
- Calculating acceleration and energy of a system undergoing simple harmonic motion.
- Calculation of the wavelength given the frequency and wave speed.
- Adding wave forms using superposition.
- Determining acceleration from a displacement–time graph.
- Calculating a decay constant and mass of isotope at a given time.

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

Section A

1. Flow of liquids

(a) Most candidates were able to suggest an appropriate unit, but for those who couldn't the most common answer was one of a volume unit without time.

(b)(i) and (ii) These 2 sections didn't prove to be difficult for most candidates.

(b)(iii) This was answered well with the most common mistake being to state that it didn't pass through all the points rather than the uncertainties. There were some answers that discussed it not being a straight line and not through the origin.

(b)(iv) Few scored well on this question, partly because the terms absolute and percentage uncertainty weren't used well. As this was about uncertainties their use was important.

(c)(i) Most were able to give the correct answer with the number of significant figures varying.

(c)(ii) This was answered well with most identifying the physical significance of the negative sign.

(c)(iii) Most were able to give a consistent value.

(c)(iv) Many were able to relate the 2 significant figures required with the data values. The most common mistake was to believe that the more significant figures the better.

(d) This was well answered by many candidates who were able to combine percentage uncertainties and calculate an absolute uncertainty.

2. Forces on a skier

(a) This was generally well-answered with fewer than expected labels of “gravity” on the vertical arrow.

(b) This was also well answered. Some candidates confused the components of the weight but the majority recognised the need to resolve the force. Very few equated N to W. There was some use of 10 ms^{-2} for g.

(c) Again well answered with the equation for balanced forces often seen.

(d) The markscheme allowed for a generous interpretation of Newton’s first law and then asked for a clear link between constant velocity and no resultant force. The answers were generally along those lines, the common fault being a statement that an object remains in motion without clarification of the nature of the motion.

3. Thermistor circuit

(a) This was poorly answered with very few candidates able to provide a suitable definition of emf. This has been the pattern over many papers.

(b)(i) This question was answered well by many candidates. Those that didn’t appreciate how to do the calculation and used the wrong p.d.s tended to choose a correct temperature based on their answer.

(b)(ii) Most candidates were able to suggest a sensible range.

(b)(iii) It was common to award the first marking point but candidates tended to finish their answers with “so the ratio increases” without discussing current or relative changes in p.d.s.

4. Ideal gas cycle

(a) Most candidates recognised that it was the area within the cycle that they needed to calculate. Too many made approximations to the shape, splitting it into 2 triangles, which led to answers that were outside the acceptable range. An approximation based on the number of 1 cm by 1 cm squares was expected.

(b) The question incorrectly stated that change AB was isothermal when, in fact, the change CD was isothermal. The markscheme was adjusted to accept a range of possible answers to ensure no candidate was disadvantaged. Despite the error, this question was well answered with the majority of candidates correctly reading values from the graph and calculating a correct value.

(c) More often than not candidates went with a standard description of entropy increasing without realising, in this case, it wouldn’t due to the cyclical nature of the process.

5. Charge-coupled device (CCD)

(a) It was common to see the magnification calculation inverted.

(b) This was generally well answered with the most common mistake being dividing the length of the CCD by 8 megapixels.

(c) This mark was often awarded for a statement that they are resolved as they are more than 2 pixels apart.

(d)(i) It seemed that candidates either knew the answer perfectly or had no idea. The few answers in between tended to invert the ratio.

(d)(ii) Unfortunately many candidates started their answer to this part by essentially repeating what they had written in the previous part of the question. They then often went on to gain the second mark for a sensible change to the image, eg brighter. Candidates who didn't understand the idea of quantum efficiency often answered this in terms of improved resolution, drawing on the question in part (c).

Section B

6. Energy sources

(a) Many candidates answered this question without referring carefully to the conditions on the island. 1 mark was often awarded for "windy" but then answers tended to talk about the wisdom of having a backup system.

(b)(i) This question was generally well answered, with the most common error being not calculating the area correctly. The conversion to GJ was done well.

(b)(ii) Many responses to this question did not mention types of energy and therefore could not be awarded any marks.

(c)(i) Most candidates were able to interpret the Sankey diagram and calculate a correct value.

(c)(ii) Responses to this question tended to be vague, missing specifics such as type of energy or the component where friction exists and thermal energy is lost. This has been a regular comment in previous subject reports.

(c)(iii) The comments above apply here as well.

(d)(i) Descriptions of the enhanced greenhouse effect were generally very good.

(d)(ii) At higher level many candidates were able to provide thorough answers to this question, discussing the absorption and re-emission of infra-red radiation by greenhouse gases and including the idea of resonance. A significant number, however, argued how greenhouse gases affected the ozone layer.

(e) Some candidates were able to correctly identify the isotopes of uranium and describe which one undergoes fission, however, many of these responses didn't describe what enrichment is, using the word enrichment as a description.

(f) The mass and atomic numbers were incorrect for Ba and Kr in this question, they appeared to have been switched in error. The markscheme was adjusted to ensure no candidate was disadvantaged and all examiners were asked to identify any candidate who appeared to have been thrown by the error. Despite the error, this question was answered well with the most common error being the choice of uranium isotope. Usually a correct number of neutrons was given for the chosen isotope.

(g) Most candidates were able to explain the function of the control rods and the moderator and some were able to identify a similarity in their operation, most commonly affecting the rate of reaction.

7. Part 1 Thermal properties of matter

(a) This was answered well by the majority of candidates with only a few confusing potential and kinetic energy.

(b)(i) Many candidates confused this with specific heat capacity.

(b)(ii) The unit in this part usually matched the definition given in the previous part.

(b)(iii) Candidates often laid out their answers in a haphazard way which made it difficult for them to get the correct energy changes. Often the melted ice wasn't taken in to consideration and temperature increases and decreases were confused.

(b)(iv) This part was poorly answered. Candidates often didn't know what the first law of thermodynamics states and most of those who did were unable to use the terms precisely.

7. Part 2 Quantum physics

(c) Many candidates didn't mention any wave properties other than diffraction and consequently weren't able to gain any marks. Those that realised they needed to discuss interference usually scored full marks.

(d)(i) This part was well answered with the majority scoring both marks.

(d)(ii) Many candidates incorporated the 3 steps required into one calculation and arrived at a correct answer. Most appreciated that they needed to give their answer to at least one more significant figure than the acceleration quoted in the question.

(e) Many made the link between the amplitude and the probability of finding at a particular position but not many appreciated that it is the square of the amplitude that is important.

(f) This part was well answered with many candidates scoring both marks.

8. Part 1 Electrical and magnetic characteristics of a loudspeaker

(a) This was well answered with the arrows drawn appropriately and in the right direction.

(b) Few candidates scored full marks here as the length of the wire in the coil was almost always incorrect.

(c) This was well answered with almost all candidates getting a correct answer.

(d) Descriptions of electromagnetic induction were surprisingly poor. “Change in flux linkage” was rarely seen nor the word “induced”. If an induced emf or current were identified it was rare to see any consequence of this discussed.

8. Part 2 Vibrations and waves

(e) Definitions of SHM were rarely complete. Many responses gave a vague description of a general oscillating system.

(f)(i) The calculation in this part of the question was generally well done but with some candidates confusing the frequency with the angular velocity.

(f)(ii) This was also well answered with the most common mistake being to forget to square the amplitude, not on paper, but when it came to using a calculator.

(g)(i) The vast majority of candidates correctly calculated the wavelength.

(g)(ii) Candidates had difficulty identifying appropriate characteristics. The fact that sound waves are longitudinal was often mentioned but this tended to be followed by description relating to superposition presumably influenced by the later part of this question.

(h)(i) The graph incorrectly suggested the time period was 8 ms and not 0.8 ms and the zero was misplaced on the *x*-axis. The markscheme was adjusted to ensure no candidate was disadvantaged and all examiners were asked to identify any candidates who had appeared to have been thrown by the error. However, very few candidates were able to discuss the phase relationship between the 2 waves and tended to talk about their superposition. Very few candidates got beyond identifying that there is 1 ms between the waves.

(h)(ii) Most candidates were able to carefully add the waves using the principle of superposition to produce the resultant wave.

9. Part 1 Kinematics and gravitation

(a) Most answers discussed that the ball was moving downwards, but didn’t realise that what was required was to state that downwards had been chosen to be the negative direction.

(b)(i) There were a number of ways to tackle this question and candidates provided some good answers. If they decided to draw a tangent at the required point it needed to be long enough to ensure they achieved an accurate result. There were a number of very short tangents being drawn which yielded a result outside the required range. Many candidates read correct co-ordinates from the graph and used them in a kinematics equation which was a more reliable method. Often, however, there was confusion between the average velocity and the final velocity.

(b)(ii) This was more reliably answered than (b)(i) as most candidates attempted it using kinematics equations.

(c) Most candidates could substitute into the formula for Newton's law of gravitation and calculate a suitable value for force. What was often missed out was the subtraction to calculate the correct distance. Few candidates made an appropriate numerical comparison with their answer for (b)(ii).

(d) This was well answered with most candidates able to calculate the correct speed.

(e) It was realised that the graph should have enabled candidates to draw in a positive direction rather than negative. A report was run to identify candidates who had attempted the question, but not gained full marks for that particular question part. Scripts were then inspected individually and additional marks awarded where necessary to ensure no candidate was disadvantaged. Despite the error, many candidates provided good sketches of the appropriate graph. Common reasons for not gaining marks were not making the parabola pass through an appropriate point near the end and drawing multiple lines.

9. Part 2 Radioactivity

(f)(i) and (ii) Many candidates were able to provide the correct answers for these parts.

(g) Most candidates didn't appreciate that it was necessary to state that, not only does radon decay quickly, it is produced slowly.

(h)(i) and (ii) The calculations in these 2 parts were done very well by many candidates. A common error in (h)(i) was to replace ln2 with 1.

(h)(iii) This was not very well answered as the majority of candidates did not address the rate of decay.

Recommendations and guidance for the teaching of future candidates

- Encourage candidates to learn definitions as an aid to the understanding of concepts.
- Encourage candidates to set out calculations in a logical and presentable fashion.
- Encourage candidates to learn the meanings of command words.
- Encourage candidates to read the examination questions carefully.
- Encourage candidates to try to use key terms in their answers. For example, questions involving energy transformation will require the types of energy involved.

Standard level paper two

Component grade boundaries

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

General comments

At SL, only 57 centres out of 511 provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage; 91% of centres thought the paper was of appropriate difficulty, the remaining 9% of centres thought it was too difficult. 50% of centres thought the paper was of similar difficulty to last year, 20% thought it more difficult and 18% thought it easier. 80% of centres thought the clarity of the wording was good to excellent, 16% thought it fair and 4% thought it poor. Again, 80% of centres thought that the presentation of the paper was good to excellent, 16% thought it fair and 4% thought it poor.

There is a considerable variation in preparedness for the examination evident between centres.

Most candidates made a serious attempt at answering the required number of questions, but in many cases they were unable to demonstrate sufficient knowledge of the content.

Poor communication, either due to poor handwriting or insufficient reasoning shown in calculations, made marking difficult in many instances. Key details were often omitted in explanations, such as the forms of energy, types of uncertainty or motion being discussed. These omissions made it difficult for the candidates to gain marks for their response.

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

- Reading questions carefully and ensuring that their response is appropriate for the command terms used in the question.
- Sequencing information in written responses, where often a concept is repeated and other key points are omitted.
- Giving standard definitions correctly, including the key details required.
- Reading axes on graphs, including powers of 10 and different scales.
- Radian and degree settings on calculators.
- Drawing tangents to curves and calculating the slope, frequently points used were not separated sufficiently to ensure accuracy.

- The ability to explain the mechanisms that lead to the greenhouse effect.
- The criteria used to determine the suitability of a line of best fit for the plotted data.
- Nuclear physics concepts such as the enrichment of fissile material and the balance of forces within the nucleus.
- Newton's laws of motion.

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

- Plotting data values, including the uncertainty.
- Calculations involving error propagation.
- Drawing and appropriately labelling the forces in a free-body diagram.
- Discussing the energy transformations during changes of state.
- Using data obtained from a Sankey diagram.
- Ability to describe the enhanced greenhouse effect.
- Calculation of the wavelength given the frequency and wave speed.
- Addition of wave forms using superposition.
- Determining acceleration from a displacement–time graph.
- Calculations involving half-life.

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

Section A

1. Flow of liquids

In general candidates found this question accessible, providing a suitable start for the examination. Most candidates were able to successfully plot the missing data point including its uncertainty and to make a reasonable attempt at propagating the uncertainty in calculations.

(a)(iii) Few were able to demonstrate the required knowledge of the criteria used to determine the suitability of a line of best-fit for the plotted data.

(a)(iv) Responses to this question rarely specified the types of error being discussed which resulted in no marks being awarded.

2. Forces on a skier

(a) Most candidates correctly drew and labelled a vector for the weight of the skier on the diagram, some incorrectly labelled the force as "gravity" while others did not have an appropriate direction or position.

(b) Finding the component of the weight normal to the slope proved a difficulty for many candidates, few drew a diagram that would have made the task easier.

(c) Interpreting the free-body diagram to analyse the forces in a given direction was difficult for many candidates.

(d) Many candidates demonstrated a poor understanding of Newton's laws of motion, either confusing the three laws or stating the first law incompletely by omitting key terms such as "uniform motion/constant velocity" and/or "net/unbalanced" force, but most could apply the laws to the skier.

3. Thermal properties of matter

(a) Candidates generally answered this question well although some did not appreciate the importance of discussing the potential and kinetic energy during a change of state.

(b)(i) and (ii) Few candidates earned a mark as they were unable to provide a complete definition or to correctly state the units.

(b)(iii) The calculation process involved several stages and few candidates sufficiently prepared their answer by considering all of the energy transformations. Common mistakes were to omit the melted ice from their calculations or to incorrectly distinguish between the temperature increase and the temperature decrease in their substitutions.

Section B

4. Energy sources

(a) Many candidates did not discuss the conditions required on the island to make these energy generation options viable, of those that did discuss the conditions few could not make three appropriate points.

(b)(i) Quite a few candidates did not find the area of the wind turbine correctly and many omitted to cube the wind speed, otherwise generally well answered.

(b)(ii) When discussing energy transfers it is crucial that the energy types are specified, many responses could not be awarded any marks due to these omissions.

(c)(i) Generally well answered, most candidates were able to interpret the Sankey diagram successfully.

(c)(ii) and (iii) Most responses were unable to be awarded marks when the specific energy types were not discussed clearly enough.

(d)(i) Many candidates were able to describe the enhanced greenhouse effect accurately but then repeated the explanation in (ii).

(d)(ii) A considerable number of candidates did not appreciate the meaning of the term "mechanism" which resulted in them repeating the description of the greenhouse effect. A large number of candidates confused global warming with the depletion of the ozone layer. Those that did discuss the mechanism were often unable to sequence the components correctly or omitted key terms. Confusing reflection or scattering with radiation was a common error in the explanations.

(e) Few candidates were able to demonstrate an accurate understanding of enrichment of nuclear fuel, if the particular isotopes of uranium involved were not stated then it was difficult to earn any marks.

(f) The mass and atomic numbers were incorrect for Ba and Kr in this question, they appeared to have been switched in error. The markscheme was adjusted to ensure no candidate was disadvantaged and all examiners were asked to identify any candidate who appeared to have been thrown by the error. Balancing the nuclear equation was generally well done with no evidence of any concern on the behalf of the candidates that the true atomic number of barium is 56 not 36 as the question might suggest. The common error was in not knowing the mass number for the fissile isotope of uranium.

(g) Most candidates were able to explain the function of the control rods and the moderator but few were able to identify a similarity in their operation.

5 Part 1 Thermistor circuit

(a)(i) The definition of emf and how it can be measured was poorly attempted by most candidates. Many incorrectly attempted to describe a method that would enable the emf to be calculated rather than defining the quantity.

(a)(ii) Of those candidates that suggested that a voltmeter could be used to measure the emf, few provided sufficient detail of how this should be done.

(b)(i) Generally poorly answered where candidates were unable to either appreciate that both resistors would carry the same current or that the sum of the potential differences across each resistor would equal the emf of the cell. Most were able to interpret their result from calculations accurately using the graph however.

(b)(ii) Most identified the low temperature end of the temperature scale was necessary but many did not identify a range which was suitably low.

(b)(iii) Few candidates were able to identify why the voltage across X increased and the voltage across R decreased resulting in incomplete responses to this question.

5. Part 2 Vibrations and waves

(c) The definition of SHM was rarely complete.

(d) Many candidates were able to accurately calculate the acceleration and energy, this depended on finding the angular velocity first, if the angular velocity was not found generally no marks could be awarded.

(e)(i) and (ii) Most candidates could correctly calculate the wavelength in (i), but could not interpret the question in (ii), not knowing what characteristics were appropriate for mention here.

(f)(i) and (ii) The graph incorrectly suggested the time period was 8 ms and not 0.8 ms and the zero was misplaced on the *x*-axis. The markscheme was adjusted to ensure no candidate was disadvantaged and all examiners were asked to identify any candidates who had appeared to have been thrown by the error. The relationship between the phases of two waves proved to be an unfamiliar term for most candidates resulting in few marks earned for (i), however the majority of candidates that attempted this question were able to accurately add the two wave forms using superposition.

6. Part 1 Kinematics and gravitation

(a) Few candidates were able to interpret this question, not realising that the significance of the negative value was the choice of direction for measurement, many simply stated the direction of motion, which did not gain any marks.

(b)(i) and (ii) Using the graph allowed a variety of approaches to this question. For those who chose to draw a tangent and calculate the gradient, frequently the tangent was not drawn long enough or the points chosen from the tangent far enough apart to provide an accurate result. Those who correctly identified coordinates from the graph and used these in equations of motion were generally more successful. All too often candidates used the average velocity for the final velocity, which did not gain more than the mark for correctly obtaining data from the graph.

(c) While most candidates could substitute values into Newton's law of gravitation and correctly evaluate the expression on the calculator, few identified the correct distance from the centre of the Earth or made a relevant comparison of their result to that in (b)(ii).

(d) and (e) The calculation of the final speed of the ball when falling near the surface of the earth was generally well done as was the sketch of the graph, although many missed out on the detail of showing the correct position of the graph. It was realised that the graph should have enabled candidates to draw in a positive direction rather than negative. A report was run to identify candidates who had attempted the question, but not gained full marks for that particular question part. Scripts were then inspected individually and additional marks awarded where necessary to ensure no candidate was disadvantaged.

6. Part 2 Radioactivity

(f) Few candidates identified that the question required the discussion of the forces between nucleons and/or that the forces need to be specified in their discussion. This proved to be a challenging question requiring specific details for an accurate response.

(g) Generally well done, demonstrating that candidates were familiar with the style of question.

(h)(i), (ii) and (iii) The majority of candidates were not familiar with depth of understanding of beta decay required for a successful response to this question. Few were able to name the antineutrino in (i) and most did not consider the mass of the electron in addition to the masses provided in (ii). Almost no candidates understood that the beta particle shares the energy released during this decay with the antineutrino and so the kinetic energy of the observed products will be less than the quantity that the mass defect would indicate.

Recommendations and guidance for the teaching of future candidates

- Encourage candidates to learn definitions as an aid to the understanding of concepts.
- Encourage candidates to set out calculations in a logical and presentable fashion.
- Encourage candidates to learn the meanings of command words.
- Encourage candidates to read the examination questions carefully.
- Encourage candidates to try to use key terms in their answers. For example, questions involving energy transformation will require the types of energy involved.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0–7	8–15	16–22	23–29	30–35	36–42	43–60

General comments

At HL, only 40 centres out of 317 provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage; 93% of centres thought the paper was of appropriate difficulty, the remaining centres thought it was too difficult. 58% of centres thought the paper was of similar difficulty to last year, 20% thought it more difficult and 10% thought it easier. 88% of centres thought the clarity of the wording was good to excellent, the remaining centres thought it fair. 90% of centres thought that the presentation of the paper was good to excellent, the remaining centres thought it fair.

The paper was prepared well; it covered the majority of understanding and skills required by the syllabus, and questions were set to well selected context and applications. The candidates proved that they had enough time for the work. Discrimination of the paper was at the proper level, the difficulty of all of the options was almost the same. Among the answers we can see many examples of good understanding in each of the questions. Almost all candidates answered all questions from two options selected. The vast majority of candidates kept responses in the answer boxes provided and if they used extension sheets they referred to this within the answer box. Handwriting seems to be at a better level than in last sessions, generally the answers were legible. Sometimes candidates referred to using coloured pencil, but there was no problem with marking in black and white.

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

Each of the questions was accessible to well-prepared candidates. However, many of the average prepared candidates failed in presenting their working in a logical and clear manner. Some candidates showed that they do not follow the key phrases and so did not answer the questions accurately. Generally, phrases such as define, show that, compare, distinguish between ... were followed by candidates better than in last sessions.

General difficulties:

- Arithmetic and algebraic mistakes, calculator mistakes.

- Power of ten (POT) mistakes in calculations.
- Layout of working in numerical questions, with a bad layout and incorrect answer it is sometimes hard to see where the mistake occurred and award partial or ECF marks.
- Sequencing the presentation of facts to support an explanation and description.
- Quite often average prepared candidates read questions superficially and, even if they wrote some quite right sentences, did not answer some of the questions.
- This session quite a high number of candidates showed lack of basic knowledge, such as basic knowledge of the solar system, the terms critical density, bandwidth, dispersion, proper time, hadrons production, neutral current.

Difficulties related to the syllabus:

- E4.3 Expanding universe and red-shift
- E4.8 Open, flat and closed universe
- F2.6 Time-division multiplexing
- F5.5 The use of Schmitt trigger
- I2.10 Difference between A-scan and B-scan

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

The best candidates have clearly seen the syllabus and presented good understanding. The well prepared candidates can analyse the situations, present working in a logical manner and use proper terminology, physical quantities and units. The majority of candidates presented the ability 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.

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

Option E — Astrophysics

One of the most popular options.

1. Solar system

Most candidates proved lack of ability to list the planets according to their mass. Even the best candidates quite often lost this mark.

2. Barnard’s star

The majority of prepared candidates presented knowledge and ability to use Wien’s law and basic characteristics of white dwarfs and red giants. Average candidates proved difficulty in algebra and unit conversions. This question well discriminated among well prepared candidates and average prepared candidates.

3. Development of the universe

Only better prepared candidates understand the concept of critical mass and were able to explain the open and closed universe in term of critical mass.

4. Mass–luminosity relation

This question was not easy, average candidates well identified star X as a main sequence star, but only better candidates were able to explain its fate. Weaker candidates had problems with basic algebra.

5. Hubble's law

This question discriminated well, the most problematic was red-shift of distant galaxies.

Option F — Communications

This option was not so popular, but a reasonable number of candidates proved good knowledge.

6. Radio communication

Generally, better candidates well answered this question, but a lot of weaker candidates do not know the term bandwidth.

7. Optic fibre transmission and the Schmitt trigger

Only well prepared candidates were able to outline the term dispersion and explain it within an optic fibre. Utilisation of a Schmitt trigger was easy only for the best candidates, the majority of average candidates were not able to use the saturation voltages from graph 1. This question discriminated well.

8. Mobile phone systems

The majority of candidates well answered and also proved ability to discuss environmental issues.

9. Satellite communication and time-division multiplexing

This question was not easy, it well discriminated among the best candidates and average candidates. Also, advantages of polar-orbiting satellites were explained only by better candidates.

Option G — Electromagnetic waves

Relatively popular option.

10. Laser light on a diffraction grating

The parts of this question related to calculation of properties of diffraction grating and wavelength were answered well. Description of the production of laser light proved a gap in knowledge and the lack of ability to write answers in a logical manner in many candidates, similarly like in previous sessions.

11. Converging (convex) lens

12. X-ray diffraction

This question well discriminated, a lot of prepared candidates answered all sub questions well, average candidates proved lack of ability to clearly derive the formula from the diagram.

13. Thin-film interference

This question well discriminated between weak and average prepared candidates, candidates who answered part (a) superficially did not outline it clearly enough to get a mark or made mistakes in the calculation in part (b).

Option H — Relativity

Very popular option this session

14. Relativistic kinematics

Part (a) very well discriminated between better and weaker candidates, many candidates did not realise that the speed mentioned was not a speed of an object. Calculations were generally done well, except part (b)(iv) which was quite difficult for the majority of average candidates.

15. Relativistic energies

Surprisingly, this question was not well answered by a lot of candidates, there was a lot of misunderstanding in the calculation in (a) and candidates often ignored principle of correspondence in (b).

16. General relativity

Many well prepared candidates presented good, well-structured and clear answers here, but a great majority of candidates ignored presence of strong Newtonian force in (b).

17. Hafele–Keating experiment

Most prepared candidates proved the ability to discuss times registered by the clocks, but often proved lack of ability to write answers clearly in a logical manner, so quite often lost a mark here.

Option I — Medical physics

Quite popular option, often well scored.

18. Hearing loss

Majority of candidates, unlike last session, wrote the definition in (a) correctly. However, reading and explaining information from a graph of hearing loss is still a real problem for many candidates.

19. Ultrasound scanning

In (a) surprisingly vast majority of candidates did not read the question carefully and did not answer the question, writing irrelevant, even incorrect sentences. Part (b) was generally well answered and well discriminated. In part (c) candidates quite often did not have enough knowledge to compare between these two methods.

20. X-rays in medical imaging

Calculations were generally well done, the explanation of fluorescent emitters was quite often misunderstood or, quite often, presented lack of knowledge in this area.

21. Radiation therapy

This question well discriminated between weak and average prepared candidates. In (c) candidates quite often mixed use of X-rays with use of radioactive material, but this was partly allowed by the markscheme.

Option J — Particle physics

Not a very popular option this session, well answered by many candidates who selected this option.

22. Particles and interactions

Many candidates showed a deep understanding of fundamental interactions, also calculations in (b) were performed well by many candidates.

23. Particle accelerators

Generally not an easy question, a lot of candidates proved lack of ability to clearly outline the motion of particles in a cyclotron and only a few candidates determined the alternating frequency of the cyclotron in (b).

24. Quarks

Well discriminating question, weak candidates proved lack of knowledge of hadron production, better candidates well answered all sub questions.

25. K meson decay

This question was generally answered well.

26. String theory and the standard model

Vast majority of candidates well distinguished standard model and string theory

Recommendations and guidance for the teaching of future candidates

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

Candidates score better in Paper 3, if they:

- are informed about aims, objectives and syllabus details in the early stages of IBDP study, and in the final stages of preparing check understanding of basic terms and definitions mentioned in the physics guide.
- are informed about standard command terms and that these terms are often used in communication between the teacher and candidate during the whole learning/teaching process. This seems to be equally important in teaching candidates who are working in their first or second language.
- study both options before revision of core physics, so at revision they can see connections between topics.
- use the data booklet when solving multistep, complex problems.
- practise with past papers.
- try not only to understand and apply, but also remember precise formulations of definitions, especially of physical quantities used only in the options.
- study options in lessons, in a group of candidates and with teacher, not on their own.
- are trained to express their ideas in written form, in a logical manner, in a proper layout, showing each step, even if “fully clear”.
- are encouraged to write some words explaining their working in calculations, derivations and other uses of formula – this can be especially helpful in not fully correct answers or alternative answers, and candidates can gain some marks for partly correct working. Also it helps if candidates can find their own mistakes in derivation, or calculation and can correct their answer.
- do not neglect units. Sporadically we can see mistakes, such as well calculated distance and time unit used or well calculated energy and unit of power used or nonsense answer given as a result of POT mistake.
- are encouraged to be careful with the difference between “equal” and “proportional”.
- are performing a whole range of empirical learning as in core physics, eg activities such as simple lab demonstrations of parallax, the location of a star in the night sky or working with a computer interactive model of an X-ray tube can significantly raise the self-confidence of the candidates in optional topics.

Candidates must be reminded that every word must be readable. The examiners must be able to read and assess the answer. Answers must be only in the boxes and on additional sheets.

Candidates should also be reminded, that incorrect answers are not penalised. The working and the answer should be crossed out only if an alternative better answer is given. Sometimes partly correct answer is crossed and no other answer is offered by some candidates.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0–4	5–8	9–12	13–16	17–21	22–25	26–40

General comments

At SL, only 57 centres out of 511 provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage; 97% of centres thought the paper was of appropriate difficulty, the remaining centres thought it was too difficult. 61% of centres thought the paper was of similar difficulty to last year, 21% thought it more difficult and 5% thought it a little easier. 86% of centres thought the clarity of the wording was good to excellent, the remaining centres thought it fair. 93% of centres thought that the presentation of the paper was good to excellent, 5% thought it fair and 2% thought it poor.

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

Option A – Polarized Light and the function of an analyser
Option B – The “electron in a box” model
Option C – The CCD
Option D – Quark confinement
Option E – Measurement of the parallax angle
Option F – Satellite communications and time-division multiplexing
Option G – Production of Laser light

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

The use of the correct equation for numerical questions in options B, E and G.

Option A – Standing (stationary) waves
Option F – Radio communication
Option G – Converging (convex) lenses

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

Option A — Sight and wave phenomena

This option was answered well overall and the candidates were well-prepared.

1. The eye and resolution

A significant number of candidates failed to recognise that the pupil of the eye is a circular aperture and used the formula for a rectangular slit. A small but worrying number described the change in shape of the eye as causing day and night vision.

2. Standing (stationary) waves

Well tackled by the majority although a surprising number of candidates could not identify a "node". Many candidates failed to find a correct value of lambda showing weak understanding of the relationship between length and wavelength for different modes of standing waves.

3. Doppler effect

In part (a) the majority of candidates could draw three successive wave fronts which were approximately circular but failed to show that the source was moving to the left. Virtually none were able to show the correct speed.

In part (b) some candidates used the Doppler equation for sound waves. Few candidates were able to score any points because they did not know how to tackle this question. Even successful candidates stated the assumption as "the speed of light being c" rather than "the speed of the x-rays being c".

4. Polarized light

Few candidates were able to describe the function of the analyser to determine if light is polarised and to explain the importance of the orientation of the analyser. The intensity calculation was performed well. In part (b)(ii) very few candidates were able to correctly draw the shape of a $\cos^2$ graph, but this point was marked generously in the MS. A small number of candidates continue to sketch multiple "hairy" lines.

Option B — Quantum physics and nuclear physics

Candidates either did very well on this option, or very poorly.

Once on the right track from question 5(b), they typically were able to answer subsequent questions correctly. Others did not appear sufficiently prepared. Throughout questions 6 and 7 candidates failed to realize that eV and GeV/c^2 cannot be used in the given equations and must be converted to J and kg respectively.

5. Photoelectric effect and de Broglie hypothesis

Definition and calculations were performed well on the whole although the definition was frequently only partial. Candidates either did not mention minimum energy or did not identify that it is for one electron from the surface.

6. Quantum aspects of electrons

Few candidates were able to gain full marks for their explanation of how the “electron in a box” model accounts for atomic energy levels. The relevance of the wave-like properties of the electron and the standing waves in the box were not understood. The majority failed to explain the link between quantized wavelength, momenta and discrete energy levels. A good majority did not give the answer to more than 1 significant figure and lost the final mark. In (b)(iii) many candidates substituted n as 3 in the main equation and just quoted the value they are supposed to show.

7. Radioactive decay

Candidates were more successful with the numerical calculation than with the explanation for the need for the neutrino. In general the responses were vague and most candidates referred to conservation of momentum and energy indicating poor interpretation of the question. In part (a) very few candidates were able to state that beta decay has a maximum value for a continuous spectrum

Option C — Digital technology

This option was attempted by few candidates. Their answers often were vague and apparently general enough to apply to any question on the topic.

8. Data capture and storage

Many candidates did not mention the photoelectric effect and the potential difference which results from capacitive action.

In part (b) the majority could define magnification but were less successful when showing that the images are resolved. Poor presentation contributed to this as it was difficult to follow the argument in the deduction process.

9. Schmitt trigger

Generally a poorly answered question.

10. Mobile phone systems

The answers were vague, or unrelated to the question.

Option D — Relativity and particle physics

Overall this question was well answered. Almost no candidates responded correctly to question 13(b).

11. Relativistic kinematics

In part (a) many failed to identify that the speed quoted was not of a physical object.

In part (b) there was some confusion with units. Some candidates seemed unfamiliar with the measurement of distance in light years. 0.85c was interpreted numerically as $0.85 \times 3 \times 10^8$ when inserted into the equation with time measured in years increasing the work involved. Candidates faced difficulty in part (b)(iii) in the multi-step nature of the question.

12. Particles and interactions

Again, the need to convert mass into kg was not always understood.

13. Quarks

Although the majority of candidates could successfully draw the Feynman diagram they were not always able to answer the question about the strong interaction and quark confinement.

Option E — Astrophysics

This was one of the most popular option choices and it was answered well overall.

14. Solar system

Part (a) was answered correctly more than part (b).

15. Barnard's star

In part (a) Wien's law was well used by the majority. In (b), although the majority of candidates could successfully identify the correct equation to determine the distance between the Earth and Barnard's star, very few were able to utilise it correctly with the data supplied in ratio form. They failed to cancel the 4π. Although it was obvious that most candidates had studied the procedure to measure the parallax angle few could reproduce them in full. In (b)(ii) a number of candidates had problems in converting between astronomical units of distances, often mistaking the units produced using the inverse of the parallax angle.

16. Development of the universe

Responses were too frequently expressed in terms of changes in the critical density. In part (a) most candidates were successful with adding the open and closed curves, but the markscheme was generous. It was common for the curves to not meet at the present time.

Option F — Communications

This was not a popular choice, but when candidates answered this option, they generally responded well.

17. Radio communication

This question was well answered on the whole except for part (b)(iv) where few candidates could identify the feature that identified the amplitude modulation.

18. Optic fibre transmission

Candidates regularly failed to explain dispersion in the context of an optical fibre and rarely identified modal and material dispersion when discussing the sources of dispersion.

19. Satellite communications and time-division multiplexing

Candidates rarely achieved full marks for the question concerning time-division multiplexing, failing to describe a series of steps, or answering without TDM at all.

Option G — Electromagnetic waves

This option was answered well, with the exception of part (b)(ii). Most candidates missed the explain part of the question and just stated the nature of the image. Use of the lens equation and calculation of magnification was done well.

20. Laser light on a diffraction grating

Very few candidates were able to demonstrate an understanding of population inversion and the way in which laser light is produced. The metastable state was incorrectly understood, if mentioned at all.

21. Converging (convex) lens

Many candidates were able to deduce an expression for the magnification of the lens starting from the lens equation. However, they were less successful when describing the nature of the image in line with the calculation done in (b)(i).

Recommendations and guidance for the teaching of future candidates

- To interpret the question and then answer just what is asked.
- Train the candidates to show all working in calculations with appropriate number of significant figures and correct unit.
- To require the candidates to practise more of the longer, explanation type of questions in order to improve the quality of written communication and comprehension.
- Use past papers and markschemes for revision.

- Require the candidates to learn definitions thoroughly so that they can be quoted fully when required, and as a basis for deduction in previously unencountered questions.
- Some candidates appeared to have memorized some key vocabulary or calculations related to the options, but were unable to apply them correctly in response to the questions. Understanding the underlying principles of the physics is as important as being able to manipulate the algebra required to complete a calculation.
- Candidates should be encouraged to rehearse their arguments in answer to the type of question that asks them to “explain”, “describe” or “outline”. Similarly, candidates need to be shown how to answer the type of question that asks them to “deduce” something. They need to know how to set out the answer so that the logical steps of the argument can be easily followed.
- Candidates should be discouraged from assuming the outcome of the deduction and incorporating it in the process (or “working backwards”).
- When asked to sketch something on to an existing drawing or graph candidates should be encouraged to work first in pencil and to only go over in ink once they are satisfied with the response. A small number of candidates drew in different colours, but the scripts are scanned in black and white, so using colour keys is of no use.

  Candidates should be discouraged from writing a series of mathematical inequalities when manipulating equations. For example, a = b/(x–y) = b/a = (x–y) is not acceptable.
- Candidates must understand when to use specific units, particularly eV and J, Gev/c^2 and kg, pc, ly and m.
- Practise the use of ratios of luminosity and brightness values.
- Practise describing the nature of an image using the sign and magnitude of u, v and m values, rather than “can be seen on a screen”.