PHYSICS TZ1 (IBA)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 30	31 - 43	44 - 53	54 - 63	64 - 73	74 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 28	29 - 40	41 - 50	51 - 60	61 - 70	71 - 100

Internal assessment

Component grade boundaries

Higher level

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

Standard level

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

IB Procedures for the May 2012 exam session

Schools are clearly aligned with the IB expectations. The cover sheet and an appropriate 4/PSOW accompanied all the IA samples, as well as candidate instructions for each investigation. A few schools included evidence of their Group 4 Project, although this is not required. The overall moderation of the May 2012 exam session ran smoothly with only a few problems. The majority of schools assessed their candidates' work in an acceptable and consistent way. Little moderation was required.

Overall, teachers knew the IA requirements, they used the appropriate forms and the sampling procedures were followed. Homemade 4/PSOW forms were for the most part acceptable, but a few schools forgot to include the boxes for the moderator and principal moderator's marks. Deadlines were met and there were very few procedural difficulties. The May 2012 exam session IA moderation ran very smoothly.

Comments unique to the May 2012 exam session

According to the 4/PSOW forms, schools are providing their candidates with rich and diverse practical programs. There is evidence of an increasing use of ICT, and the majority of candidate lab reports are word processed with computer-generated graphs. The majority of schools are also demonstrating appropriate treatment of errors and uncertainties. Unfortunately, there are a few schools that are allowing candidates to hand draw graphs, without graph paper; connecting data point to data point. There is a well-established set of teacher prompts for the Design criterion, and most candidates are doing good job at this. Occasionally, however, teachers still require a hypothesis for Design, but candidates are not penalized for this. Also, occasionally, a teacher's prompt may contain two variables. This makes it impossible for the candidate to select an appropriate independent variable. Finally, a few schools are treating Design as a research topic, allowing candidates to use textbooks and the Internet. This is totally inappropriate as it leads to established and standard investigations, including relevant equations.

Many schools are now assigning only two investigations, each assessed by all three criteria. This is unfair to the candidate, as they have no opportunity to improve their work. This is especially worrisome when a candidate earns low marks.

A number of schools are giving their candidates an IA checklist; this is most helpful to the candidate as it often spells out the details of the IA expectations. This is good practice and is encouraged. Finally, the majority of teachers are marking their candidate's work with brief comments and IA criteria achievement levels. This candidate feedback benefits them and helps the moderators justify the teacher's mark. This practice is encouraged.

The range and suitability of the work submitted

There was ample evidence that most centres are providing comprehensive practical programs, covering a wide range of investigations. The use of ICT is now commonplace, and the majority of candidate reports are word-processed and graphs are presented using appropriate software. The required hours of practical work do not seem to be a problem, and there is evidence of good syllabus coverage. Teachers are reminded that investigations can be on topics not found in the syllabus.

Some centres still have candidates provide a hypothesis for their design investigations; although this is not penalized it can inhibit the open-ended nature of the candidate's design. Also, when candidates already know the relevant theory and equations, assessing design is not always appropriate.

Teachers must be careful when giving the dependent variable in the Design prompt, as there were a few cases where candidates were also given the independent variable. There were a number of cases where the candidates actually had two independent variables, such as changing the mass by changing the size of a ball. The teachers should have caught this major mistake and guided the candidate to a more productive approach. General guidance is allowed.

The Group 4 Project seems to be well integrated into the practical programs. Once again, a few centres provided evidence of the project but evidence is not required (only an indication of the date and hours on the 4/PSOW form).

Candidate performance against each criterion

Design

Teachers have mastered the art of giving design prompts. However, in a few cases, the prompts were not appropriate, such as asking candidates to design an investigation to measure gravity or to confirm Ohm's law. Good design prompts should have candidates looking for a function between two variables, not a specific value. Candidates need to be reminded that for a complete to be awarded in Design variables need to be defined (and vague statements like "I will measure the time" need to be clarified as to just how this will be done). Operational definitions help in the design of a method as well. This comes under the ability to control variables.

Data Collection and Processing

Candidates tend to have the most success with DCP. Raw data always has uncertainties. Moderators are looking for a brief statement as to why the candidate has given a particular value of uncertainty, and this holds for both raw and processed data. Significant figures and the least count of measuring devices are relevant here. To be awarded a complete in DCP candidates are expected to have produced a graph.

There were some cases where graphs would have been relevant but candidates just made calculations. These cases cannot be awarded complete for DCP aspect 3. Teachers need to be aware of this expectation. Also, it is important that the candidate (and not the teacher) decides what quantities to graph and how to process the data.

Conclusion and Evaluation

This can be the most difficult criterion to earn full marks, especially aspect 1, and it is often over-marked by the teacher. 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, or the y-intercept for some physical meaning. Candidates might even give the overall relationship some physical interpretation (perhaps a hypothesis). Teachers need to look for this when awarding aspect 1 a complete, as moderators often had to change a "complete" to a "partial". Finally, if candidates perform a standard and well established physics lab, and CE is assessed, then it is unlikely that they can come up with weaknesses or improvements. CE is best assessed when candidates have also designed and performed the investigation themselves.

Recommendations for the teaching of future candidates

- Candidates need a clear understanding of the IA criteria. To help with this, the teacher could give candidates a copy of a really good IA; one that earned all completes.

- Candidates need to be trained in achieving the IA aspects. Group work, teacher guidance, even peer review can help but of course in such cases the teacher would not mark the IA for an IB grade on the 4/PSOW.

- It is important that when practical work is assessed that the candidate works alone. This does not mean, however, that another candidate cannot help, and for example release a ball from a given height while the first candidate measures the time. All measurements must come from the candidate being assessed. Occasionally moderators find identical data sets and then they are suspicious. Also, research on the Internet or in the library is not appropriate.

- Lab reports should have descriptive titles, like “How The Length of a Pendulum Affects the Period” and not “The Pendulum”.

- Teachers that included comments on the candidate report or on attached sheet that stated exactly what level of achievement and why they awarded the mark often were not moderated up or down, as such detailed attention to assessment allows an appropriate level of marking and is usually justified by the teacher. This practice is encouraged.

Further Comments

One issue that came up several times in the May 2011 session was the matter of assessing aspect 3 of Design and the issue of sufficient data. Although teachers expect explicit reference to this in the preliminary aspects of the candidate’s report, there are cases where evidence for this can be found in what is considered the data collection and processing part of the candidate’s report. Normally, candidates mentioned repeated measurements, but if they fail to mention this but clearly take repeated measures and use the average, then we will still give the candidate credit for this (similarly, for the range and number of data points). If the data table reveals a sufficient number and an adequate range, then the expectation under Design will still be met. The moderators are giving the candidate the benefit of doubt here, and are not punishing candidates for not doing exactly what the moderator would like to see. Instead, the moderator looks for evidence to give a candidate credit.

Most teachers assessed appropriate work and awarded appropriate marks. Moreover, most candidates were working hard and producing good physics lab reports. However, teachers are reminded that design investigations are not meant to be research projects. Searching the Internet is not appropriate.

Moderators normally kept the teachers’ marks, but occasionally they raised or lowered marks. If there is a trend, teachers tend to over-mark the Conclusion and Evaluation criterion. If the teachers have applied the criteria appropriately then the moderation system should support them. Moderators are not there to apply their own pet theories and practices as teachers, but to ensure that the centres are using the criteria within acceptable bounds according to the official descriptors. In other words, moderators are looking for the systematic error beyond the random error in the application of the aspects of the criteria.

The next sections contain the advice that physics IA moderators follow.

When moderators mark down—Design

The moderator will mark down when the teacher gives a clearly defined research question and/or the independent **and** controlled variables. The teacher may give the candidate the dependent variable (as long as there are a variety of independent variables for the candidate to identify). Giving the candidate the general aim of the investigation is fine if the candidate has significantly modified the teacher prompt or question (e.g. made it more precise, defined the variables). The moderator will mark down when a method sheet is given which the candidate follows without any modification or **all** candidates are using identical methods. Standard laboratory investigations are not appropriate for assessment under Design.

When moderators mark down—Data Collection and Processing

The moderator will mark down when a photocopied table is provided, with headings and units already complete, for candidates to fill in. If the candidate has not recorded uncertainties in any quantitative data then the maximum given by the moderator is "partial" for aspect 1. If the candidate has been *repeatedly inconsistent* in the use of significant digits when recording data then the most a moderator can award is "partial" for aspect 1. In physics, data is always quantitative. Drawing the field lines around a magnet does not constitute DCP.

The moderator will mark down when a graph with labeled axes is provided (or candidates have been told which variables to plot) or candidates follow structured questions in order to carry out data processing. For assessment under DCP aspect 3, candidates are expected to construct graphs. For a complete, the data points on the graph should include uncertainty bars, and the uncertainty in the best-straight line gradient needs to be calculated.

When moderators mark down—Conclusion and Evaluation

If the teacher provides structured questions to prompt candidates through the discussion, conclusion and criticism then, depending on how focused the teacher's questions are and on the quality of the candidates' responses, the maximum award is partial for each aspect that the candidate has been guided through. The moderator judges purely on the candidates input. The difference between a partial and a complete for CE aspect 1 involves the justification of their interpretation of the experimental results. This is a difficult task, and it can involve physical theory.

In the following cases the moderator will support the teacher's stance, as they are aware of their own expectations of the candidates.

When moderators do not mark down—Design

Moderators do not mark down when the independent and controlled variables have been clearly identified in the procedure but are not given as a separate list (we mark the whole report and there is no obligation to write up according to the aspect headings). Moderators do not mark down when there is a list of variables, and it is clearly apparent from the procedure which variable is independent and which is controlled.

Moderators do not mark down when similar (but not word for word identical) procedures are given for a narrow task. The moderator will make a comment on the poor suitability of the task on 4/IAF form. Moderators do not only mark the equipment list, they give credit for equipment clearly identified in a stepwise procedure. Remember, moderators look at the whole report. Moderators do not insist on ± precision of apparatus to be given in the apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DCP. Moderators do not downgrade a teacher's mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Moderators support the teacher's stance here.

When moderators do not mark down—Data Collection and Processing

In a comprehensive data collection exercise possibly with several tables of data, if the candidate has been inconsistent with significant digits for just one data point or missed units out of one column heading, then the moderator will not mark down this minor error. If the moderator feels the candidate has demonstrated that they were paying attention to these points and made one careless slip then the moderator can still support maximum marks under the "complete not meaning perfection" rule. This is an important principle since good candidates responding in full to an extended task are unfairly penalized more often than candidates addressing a simplistic exercise. The candidate is not marked down if they have not included any qualitative observation(s) and the moderator cannot think of any that would have been obviously relevant. The moderator does not mark down if there is no table title when it is obvious what the data in the table refers to. Often candidates do all the hard work for DCP and then lose a mark from the teacher because they did not title the table. Except for extended investigations it is normally self-evident what the table refers to.

The expectation for the treatment of errors and uncertainties in physics is described in the Subject Guide and the TSM. Both SL and HL candidates are assessed on the same syllabus content and the same standard of performance.

All raw data is expected to include units and uncertainties. The least count of any scale or the least significant digit in any measurement is an indication of the minimum uncertainty. Candidates may make statements about the manufacturer's claim of accuracy, but this is not required. When raw data is processed, uncertainties need to be processed (see the Subject Guide, syllabus details 1.2.11).

Candidates can estimate uncertainties in compound measurements (± half the range), and they can make educated guesses about uncertainties in the method of measurement. If uncertainties are small enough to be ignored, the candidate should note this fact.

Minimum and maximum gradients should be drawn on linear graphs using uncertainty bars (using the first and last data points) for only one quantity. This simplified method becomes obscured when both graph quantities contain uncertainty bars. Other uncertainty analysis is expected when graphs are non-linear.

If the candidate has clearly attempted to consider or propagate uncertainties then moderators support the teacher's marking even if they may feel that the candidate could have made a more sophisticated effort. If propagation is demonstrated in part of the lab then full credit can be awarded even if error analysis is not carried through in every detail (as long as the candidate has demonstrated an appreciation of uncertainty then they can earn a complete).

Moderators **do not** punish a teacher or candidate if the protocol is not the one that is taught i.e. top pan balance uncertainties have been given as ± 0.01g when teachers may feel that if the tare weighing is considered then it should be doubled. Moderation is not the time or place to establish a favoured IB protocol.

When moderators do not mark down—Conclusion and Evaluation

Moderators often apply the principle of “complete not meaning perfection”. For example, if the candidate has identified the most sensible sources of systematic error then the moderator can support a teacher’s marking even if the moderator can identify one more. Moderators are a bit more critical in the third aspect that the modifications are actually relating to the cited sources of error. If the moderator feels a task was too simple to truly meet the spirit of the criteria, then they will comment on the 4/IAF as to the unsuitability of the task giving full justifications. This will be provided in feedback but the moderator will not necessarily downgrade the candidate.

The most challenging aspect of CE is the differentiation between a “partial” and a “complete” under aspect 1: “States a conclusion, with justification, based on a reasonable interpretation of the data”. A justification may be a mathematical analysis of the results, one that includes an appreciation of the limits of the data range, but it might also be an analysis that includes some physical meaning or theory, even a hypothesis (though a hypothesis is not required). To earn a complete in CE (aspect 1) serious and thoughtful comments are required; something beyond “the data reveals a linear and proportional relationship”.

Paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 14	15 - 19	20 - 24	25 - 27	28 - 31	32 - 40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 14	15 - 16	17 - 19	20 - 21	22 - 29

General comments

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

Only a small percentage of the total number of centres taking the examination returned G2’s. For SL there were 73 responses and for HL there were only 27 responses. Consequently, general opinions are difficult to assess since those sending G2’s may be only those who feel strongly in some way about the Papers. The replies indicated that the May 2012 papers were generally well received, with many of the G2's received containing favourable comments. The majority of the teachers who commented on the Papers felt that they contained questions of an appropriate level (100% at HL and 96% at SL). At HL 18% thought that the paper was easier compared to that of the previous year and 7% thought it was harder. At SL, 16% thought it was easier and 6% thought it harder than last year's papers.

At HL, 94% of the responses indicated that the Paper gave satisfactory or good coverage of the syllabus and at SL this percentage climbed to 97%. When commenting on coverage, it should be borne in mind that this must be judged in conjunction with Paper 2. All teachers that returned G2's felt that the presentation of the Papers was 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 greyed 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.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	1565	612	341	214	3	57.22	0.42
2	372	2194	88	79	2	80.22	0.36
3	1891	170	642	29	3	69.14	0.37
4	178	436	1607	510	4	18.65	0.13
5	298	1632	217	584	4	59.67	0.47
6	122	761	1769	80	3	64.68	0.12
7	253	458	1811	209	4	66.22	0.37
8	126	1853	558	194	4	67.75	0.28
9	1754	381	435	161	4	64.13	0.49
10	224	199	774	1533	5	56.05	0.49
11	1361	699	350	322	3	49.76	0.57
12	185	931	772	839	8	34.04	0.06
13	1316	525	325	565	4	48.12	0.42
14	133	484	445	1667	6	60.95	0.23
15	340	1142	1008	241	4	41.76	0.52
16	49	2325	289	70	2	85.01	0.36

17	76	1944	400	310	5	71.08	0.48
18	122	512	2067	30	4	75.58	0.37
19	1050	207	346	1127	5	41.21	0.51
20	446	498	388	1401	2	51.22	0.42
21	459	282	1307	685	2	47.79	0.42
22	584	315	447	1384	5	50.6	0.2
23	1185	1229	151	167	3	43.33	0.3
24	360	1696	461	214	4	62.01	0.61
25	1615	143	250	718	9	59.05	0.52
26	503	256	1505	466	5	55.03	0.57
27	2299	193	90	151	2	84.06	0.33
28	622	54	505	1551	3	56.71	0.63
29	554	1864	225	85	7	68.15	0.42
30	599	148	1687	298	3	61.68	0.43
31	1381	799	367	176	12	50.49	0.54
32	288	421	357	1665	4	60.88	0.48
33	781	435	1204	312	3	44.02	0.39
34	233	1001	1351	144	6	49.4	0.16
35	659	825	192	1053	6	24.1	0.38
36	48	282	419	1984	2	87.86	0.18
37	1696	440	81	509	9	18.61	0.28
38	66	138	2306	222	3	84.31	0.26
39	276	256	1568	625	10	57.33	0.46
40	353	486	1188	705	3	43.44	0.39

Total number of candidates: 2735

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	1440	3031	663	504	1	53.75	0.49
2	2795	1633	661	541	9	49.57	0.45
3	1081	3762	408	386	2	66.71	0.58
4	2567	2019	564	483	6	45.52	0.53
5	499	913	3483	743	1	13.18	0.11
6	485	1073	780	3290	11	58.34	0.56
7	866	1053	3385	330	5	60.03	0.38
8	883	2732	788	1227	9	48.45	0.46
9	267	3736	809	819	8	66.25	0.39
10	464	536	1401	3234	4	57.35	0.43
11	461	1610	3180	384	4	56.39	0.15
12	2951	876	1289	515	8	52.33	0.49
13	1879	300	1325	2126	9	37.7	0.38
14	984	2287	1435	927	6	40.56	0.26
15	2021	1280	1230	1105	3	35.84	0.49
16	651	822	3175	984	7	17.45	0.14

17	179	3774	1293	390	3	66.93	0.57
18	326	3201	999	1104	9	56.77	0.49
19	468	1658	3375	133	5	59.85	0.53
20	3209	483	766	1175	6	77.75	0.25
21	1186	1182	1409	1849	13		
22	4331	473	300	529	6	76.8	0.4
23	1488	165	3693	286	7	65.49	0.3
24	472	2004	2754	403	6	48.84	0.27
25	2527	2705	242	158	7	47.97	0.46
26	1230	1568	561	2270	10	21.81	0.36
27	3206	1183	448	789	13	56.85	0.51
28	1787	479	2875	483	15	31.69	0.23
29	193	813	883	3740	10	81.99	0.26
30	3331	1400	227	653	28	11.58	0.17

Total number of candidates: 5639

Comments on the analysis

Difficulty

The difficulty index varies from about 19% in HL and 12% in SL (relatively 'difficult' questions) to about 85% in HL and 77% in SL (relatively 'easy' questions). The majority of items were in the range 35% to 70%. Thus, the Papers provided ample opportunity for all candidates to gain some credit and, at the same time, gave an adequate spread of marks.

Discrimination

All questions, with one exception, had a positive value for the discrimination index. Ideally, the index should be greater than 0.2. Only three questions at HL had a discrimination index less than 0.2 and five at SL. 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, but especially at SL, the number of blank responses tends to increase towards the end of the test. This may indicate that candidates did not have sufficient time to complete their responses, despite a lack of comments from teachers to this effect. Even so, this does not provide an explanation for 'blanks' early in the Papers. Candidates should be reminded that there is no penalty for an incorrect response. Therefore, if the correct response is not known, then an educated guess should be made. In general, some of the 'distractors' should be capable of elimination, thus reducing the element of guesswork.

Comments on selected 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. At SL, Q20 was allowed to have two correct responses and the same applies also to the common question HL, Q36/SL Q29. At SL Q21 was deleted because the question is off syllabus.

SL and HL common questions

SL Q3 and HL Q2

There were a few comments on the G2 forms about the use of the term "displacement". Displacement is generally understood as the vector from a fixed point to the position of a particle. As the particle moves, the position and hence the displacement vector, changes. Thus it is perfectly correct to ask about the "change in the displacement".

SL Q5 and HL Q4

In this question the majority of candidates thought, incorrectly, that the ball would be in equilibrium at the central position when the string is vertical. The ball is obviously not in equilibrium since it is moving on a circular arc and so at the vertical position there must be a net force directed towards the centre of the arc and so there cannot be equilibrium.

SL Q29 and HL Q36

The great majority of candidates chose option D (deforestation) as a cause of increase in global warming. However, it can be argued that option C (increase in mean sea level) also can lead to an increase in global warming and so both answers were accepted. (The reason being that with more water surface area, as opposed to land, the average albedo would decrease.)

HL Questions

Q12

This question concerned itself with phase difference in a standing wave. It appears not to be well known that particles within any one loop are in phase with each other and that two particles in *adjacent* loops differ in phase by 180°.

Q15

The majority of the candidates got the answer to this question but an almost equal number thought that the refractive index was given by the ratio of sines in option C. This shows clearly that candidates thought they were dealing with Snell's law and not Brewster's law.

Q23

The statistics of the question show confusion among the candidates who were obviously unclear about how to get the direction of the magnetic force on electrons.

Q26

It must be known that a unit for mass that is convenient in atomic and nuclear physics is $MeVc^{-2}$.

Q31

There appeared to be a difficulty in obtaining the correct wavelength for the electron “in the box” model for the state $n=1$. The wavelength is $\lambda=2L$ and so by de Broglie’s hypothesis the momentum is $p=h/\lambda=h/(2L)$.

Q35

There is some evidence that candidates may have misunderstood this question. The neutrons produced in fission are too fast and so must be slowed down if fission is to continue, hence the answer is A. Some candidates obviously thought that with more neutrons more fission reactions were to take place and so chose D. However, unless the energy of the extra neutrons is specified this is in general an incorrect statement.

SL Questions

Q9

This is a question straight from the Guide which states that internal energy consists of the intermolecular potential energy of the molecules of a substance plus their random kinetic energy.

Q14

The majority of candidates answered this question correctly. Candidates are expected to recall the orders of magnitude of the wavelengths of the principal radiations in the electromagnetic spectrum, as stipulated by the Guide. It can be argued that a more distinct wavelength could have been chosen so as to avoid possible confusion with the area between “soft” X-rays and UV but the statistics of the question do not indicate that candidates were upset by this choice.

Q16

The majority of candidates chose the number of electrons flowing past a point in a given time as the definition of the ampere when the correct answer is in terms of a force between parallel currents.

Q20

The majority of candidates chose option A that states that the electric field is the same everywhere in between the plates. The examining team felt that this deserved credit and so this option along with option D (field being weaker at the edges) were both accepted.

Q21

This question dealt with electric potential, a topic that is not part of the SL syllabus. The question was therefore deleted. The examination team apologizes for the logistical error of including this HL question in the SL paper as well.

Recommendations and guidance for the teaching of future candidates

Candidates should make an attempt at every item. Where they cannot provide the correct response, then they should always choose that option which, to them, appears to be most likely. It should be emphasized that an incorrect response does not give rise to a mark deduction.

The stem should be read carefully. 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.

Having decided on the correct response, candidates should check that all other options are not feasible.

Candidates should consult the current Physics Guide during preparation for the examination, in order to clarify the requirements for examination success.

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 Subject Guide. Ample time should be apportioned to the teaching of such topics as Global Warming and the Greenhouse Effect. The common knowledge that most people have about these areas of the Guide is not always sufficient to answer questions on these topics.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 28	29 - 40	41 - 49	50 - 58	59 - 67	68 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 18	19 - 24	25 - 29	30 - 35	36 - 50

The number of G2 forms received from SL centres was 81, and the number received from HL centres was 28. The feedback from teachers on the G2 forms is summarized as follows.

Standard Level

- 95% thought the level of difficulty appropriate, while 2.5% thought it too easy and 2.5% too difficult.

- 49% found the paper of a similar standard to last year. 16% found it a little easier and 3% much easier, while 18% found it a little more difficult. No one found it much more difficult.
- 52% thought the clarity of wording good and 44% thought it satisfactory, with 4% thinking it poor.
- 60% found the presentation of the paper good and 38% found it satisfactory, whereas 3% found it poor.

Higher Level

- 93% thought the level of difficulty appropriate, while 7% thought it too difficult. No one thought it too easy.
- 50% found the paper of a similar standard to last year. 25% found it a little easier, and 4% found it much easier. 14% found it a little more difficult, while no one found it much more difficult.
- 52% thought the clarity of wording satisfactory and 48% thought it good. No one thought it poor.
- 60% found the presentation of the paper good and 40% found it satisfactory. No one found it poor.

General comments

The majority of candidates appeared to find the paper accessible with many examples of good understanding of the material. There was no evidence that candidates were short of time to complete their work.

A general view that emerged from G2 comments and from the examining team was that the paper was no easier than previous years in terms of the physics content, but was easier for candidates to access in terms of the language used. Non-native speakers of English in particular seemed to find the questions easier to understand and were therefore better able to communicate their knowledge.

In HL, B1 and B2 were the optional questions most commonly answered, followed by B3 and then B4. It was notable that when candidates answered B3 part 2 on digital data storage or B4 part 3 on atomic energy levels, they either did very well or very poorly.

In SL, B3 was by far the most popular option. Candidates seemed comfortable with kinematics and electricity.

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

Most questions seemed to be quite accessible to candidates who were well prepared for the exam. However, the areas identified by the examination team as being particularly difficult were as follows:

- Finding the gradient of a straight line in a sensible way (e.g. using a large triangle or using obvious points on the line such as the origin and end point). In almost every exam session, question A1 requires this skill.
- Giving clear definitions (e.g. radioactive decay, binding energy, specific heat capacity, Lenz's law, simple harmonic motion, the principle of superposition, inelastic collision, most significant bit).
- Derivations of equations, e.g. B1 part 1 (b) (i) on the power of a wind turbine.
- Questions starting with the command term *explain* or *deduce*. Responses were generally incomplete and statements were made without any explanation.
- Appreciating that there is often a conceptual connection between successive parts of a question (e.g. in question A6 in HL).
- Outlining how two polarizers can be used to measure the concentration of sugar solutions.
- Lenz's Law and electromagnetic induction.
- Drawing Sankey diagrams.
- Explaining entropy changes.
- Calculations using equations for simple harmonic motion.
- The difference between DVDs and CDs.
- Determining the uncertainty in momentum.

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

- The data analysis question (except for calculating gradient)
- Sketch graphs of simple harmonic motion
- Thermodynamic processes
- Calculations in general and in particular on simple harmonic motion, Doppler effect, projectile motion, gas laws, Newton's laws and momentum, electric circuits, radioactive decay and simple collisions

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

A1 (HL and SL) Data Analysis

(a)(i) Often well done but major errors included drawing a trend line through (0,0) or drawing a curve to fit the data points and the origin. The question specifically asked for a straight line.

(a)(ii) Usually well done. Most of the incorrect responses stated that the trend line did not pass through all error bars. The point is that even though a straight line can be drawn through the error bars, the relationship is still not proportional because the line does not pass through the origin.

(b)(i) Very well done.

(b)(ii) Most candidates did reasonably well. Most took the approach of working out the % uncertainty and doubling it. There was a generally good use of significant figures. Some candidates doubled the absolute uncertainty to get 0.2. While this gives the correct answer, this approach is wrong and did not gain any credit.

(b)(iii) Many candidates took a cumbersome approach to finding the gradient of the line. By far the easiest approach was to make a triangle with the points (0,0) and (12,3.5), or to insert the values 12 and 3.5 into the equation. Many candidates chose two difficult points close together, or a data point that was not on the best-fit line. There was much confusion about whether the gradient was equal to k or k^2, and consequently many candidates did not gain the third mark.

(b)(iv) Not many candidates got this right, finding the $m^{½}$ difficult. The question was in some ways testing dimensional analysis in addition to understanding units.

A2 (HL) and B1 part 2 (SL) Radioactive Decay

(a) A complete description of natural radioactive decay was lacking for many, with few gaining all three marks. Some indicated that the nucleus was unstable but failed to indicate it becomes more stable as a result of decay. Looking to the command term used and number of marks required indicates the depth of answer required.

(b)(i) Most candidates answered correctly.

(b)(ii) Many candidates earned the first marking point with some reference to mass lost during the process. Many candidates did not answer the question that asked, which required mass-energy equivalence to be explained.

(b)(iii) Quite poorly done – often described as the “energy holding the nucleus together”.

(b)(iv) Generally well done. Many candidates multiplied by the number of neutrons or protons instead of nucleons, gaining partial credit. Another common mistake was to just use the values for binding energy per nucleon and not multiply by anything.

A2 (SL only) The Greenhouse effect

(a) Some candidates were able to correctly explain the meaning of the terms in the equation, namely the intensity of the Sun’s radiation at the Earth’s orbit, the fraction absorbed after reflection and the disc of illumination. The first term was often identified as just power rather than intensity (power per square metre) at the Earth’s orbit. The second term was often identified as an atmospheric effect rather than as an effect of the surface and as a result the word 'absorbed' was rarely seen. For the third term, many answers incorrectly referred to the surface area of the Earth as opposed to the area of the surface exposed to the Sun’s radiation.

(b)(i) This seemed like quite a complex substitution, but many candidates were able to complete this correctly. Many candidates did not know how to take the 4^{th} root and calculated the square root instead. Another common problem was forgetting to square d.

(b)(ii) Many candidates were too vague in their explanation, not specifically mentioning 'greenhouse gases' in their explanation for example. There were many incorrect references to the ozone layer here. Also, several candidates simply stated a reason, rather than providing an explanation.

A3 (HL and SL) Thermal energy transfer

(a) Usually well answered.

(b)(i) Generally well done. Bizarrely, a very common error was to make a mistake in subtraction to find a temperature difference, e.g. giving (44 - 20) = 22. Some found the correct temperature difference but then converted that value to Kelvin.
(b)(ii) Most got the first mark but few elaborated to get the second mark. The direction in which the measured value would vary from the theoretical value is a subtle point but important to appreciate.

A4 (HL only) The Doppler effect

(a)(i) and (a)(ii) Generally well done, although it was common for the wrong sign to be used in the denominator.

(b) Very few candidates got all three marks here. A seemingly simple question but actually very subtle. The fact that when the source is moving the observed wavelength (but not the wave speed) is different and when the observer is moving the observed wave speed (but not wavelength) is different is difficult to appreciate. When teaching the Doppler effect, it is important to understand the underlying physical reasons for the change in observed frequency, as well as being able to do calculations correctly.

A5 (HL only) Polarization

(a) The majority of candidates gave good answers here; incorrect answers often showed a sine curve instead of $\cos^2$.

(b) In the first alternative, many candidates got the third mark for realizing that the intensity of transmitted light is a measure of concentration. Some got the second mark for realizing that the plane of polarization is rotated by the sugar solution. Almost no one got the first mark for mentioning crossed polarizers. This is important because the intensity of transmitted light only gives a measure of concentration if the initial intensity is zero. Not many candidates took the approach indicated in the second alternative.

A6 (HL only) Electromagnetic induction

(a) Poorly done in general. Correct, concise statements of Lenz’s law were few and far between. Some candidates quoted Faraday's law or equation about the magnitude of induced emf as opposed to its direction.

(b) Very poorly done. Many candidates did not realize the conceptual link between parts (a) and (b) and did not think to apply Lenz’s law to the situation. Many thought there would be a horizontal force that would delay the time of flight to the ground, betraying a misunderstanding of projectile motion as well as electromagnetic induction. Some gained marks for mentioning induced current/emf and for mentioning an upward force. There were very few answers given in terms of energy, although it may be easier to understand this phenomenon in that way. Teachers should emphasize to candidates that Lenz's law is in fact a special case of the conservation of energy, and that it is often easier to answer questions adopting this approach, rather than going into the complexities of induced currents and the directions of their associated magnetic fields and forces.

B1 Part 1 (SL and HL) Wind power

(a) Answers often did not outline energy conversions clearly, as required by the question. Many did not mention the energy form of the wind, i.e. kinetic. Many did not mention the generator. Many candidates did not realize that they should outline the mechanism that causes the change along with the energy change, as is common in questions of this type.

(b)(i) Many candidates incorrectly took the wind turbine power formula from the data booklet and substituted an expression for the area of a circle. This is not a deduction. Questions of this nature require the use of basic physical principles (kinetic energy, density and mass per unit time) to develop an equation in a clearly identifiable series of steps.
(b)(ii) Most candidates described some type of friction, but not many made mention of a moving part. Not many made the point that the speed of wind cannot drop to zero or that some air must pass through the turbine (otherwise the wind would come to a dead stop and no more wind would be able to come through).

(c) Many candidates subtracted the values for wind speed and/or density and plugged these values into the power equation. This is completely wrong and did not gain any marks.

(d) Most candidates knew how to construct a Sankey diagram of some form, although labelling was not very precise. Not many labelled the power loss arrow correctly.

(e) Well answered.

B1 Part 2 (HL only) Projectile Motion

(a)(i) Most candidates realized that there is no horizontal acceleration.
(a)(ii) The drawing for the vertical component was the weakness here, with a variety of curves drawn as opposed to a straight line through the origin.

(b)(i) and (ii) A basic calculation, well done.

(c) Most candidates gained the first two marks, but most curves were drawn symmetrical. The fact that due to horizontal deceleration, the distance travelled in the second half is less than the first half is a fairly subtle point.

B2 Part 1 (SL and HL) Simple harmonic motion and superposition of waves

(a) Very variable, a full range of answers given for what is a basic definition and very learnable.

(b)(i) Generally well done. The most typical error was to draw some sort of sinusoidal shape, passing through the origin.
(b)(ii) Most who got (b)(i) got this correct and vice-versa.

(c)(i) Well done in general. The most common error was to go further than one period.
(c)(ii) Most who got (c)(i) got this correct and vice-versa.

(d) This calculation was difficult for candidates. Many candidates earned the 1st marking point for calculating ω only. Quite a few tried to answer using speed = distance/time. Some got confused with algebra, failing to realize that the square root of x^2 is of course x.

(e)(i) Statements of the principle of superposition were often given in terms of just "constructive and destructive interference" or the "sum of amplitudes" rather than the vector sum of displacements.
(e)(ii) Many did not correctly draw the future position of the wave, and indicated maximum displacement at 3 and 7 m. Many correct answers were seen, however.

B2 Part 2 (HL only) Thermodynamics

(a) An easy question for most.

(b) Many candidates went through the more cumbersome $PV = nRT$ route.

(c) Many candidates calculated the work done from $p\Delta V$ correctly, but then subtracted from ΔU instead of adding.

(d) (i), (ii) and (iii) Very few candidates gave adequate explanations.

B3 Part 1 (SL and HL) A collision

(a) Well answered, but quite a few determined distance incorrectly, neglecting to subtract 0.025 m per block.

(b)(i) Many did not realize that kinetic energy must be conserved for the collision to be elastic. There was some confusion with conservation of total energy (including thermal) and momentum, both of which are of course always conserved in elastic and inelastic collisions. Many candidates believed that the collision had to be elastic because the blocks did not stick together. This is erroneous and needs to be emphasized in teaching. Some candidates believe that if a collision is not 100% inelastic, i.e. both objects come to a dead stop, then it must be elastic.

(b)(ii) A number of mathematical errors were made in this question, for example confusing 20% loss with 80% loss, but many candidates earned at least some marks.

(c)(i) The most common answer was " To every action there is an equal and opposite reaction". While this is a common formulation, it is a loose statement of the law at best and physicists need to be able to give a more precise statement than the general population. The statement given in the markscheme is superior.

(c)(ii) This was generally well done. The most common error was not to have the arrows acting through the middle of the blocks.

(c)(iii) Most candidates failed to realize that the change in velocity is 0.18 **plus** 0.16, but otherwise the formula was well used. When teaching momentum, the vector nature of this quantity, even in linear situations, need to be emphasized.

B3 Part 2 (HL only) Digital data storage

(a) The analogue signal was done well, but many had more than two values for digital. It was very common for the digital signal the graph consisted of a sine curve with lots of little steps in it.

(b) There were many correct answers, but many thought that most significant bit is the first 1 rather than the first digit (whether 0 or 1). Some textbooks give incorrect definitions of this. In this example of a five digit binary number, it is clear that if the first 0 were changed to a 1, this would have the biggest effect on the number.

(c)(i) There were some good answers, but not many mentioned the binary 0 and 1.
(c)(ii) Only some candidates mentioned the smaller wavelength used in DVDs, but many still had the idea of pits and lands being closer together.
(c)(iii) The calculation of pit depth proved challenging. Most candidates did one step or the other correctly, but not both.

B4 Part 1 (HL) and B2 Part 2 (SL) Gravitational fields

(a) The first two marking points were rarely awarded, but most candidates gained last two marks. Many candidates gave the formula and defined the terms, but neglected to mention that the force is always attractive or that the masses need to be point masses.

(b) This question was very well done.

(c) This was difficult for the vast majority of candidates, in particular taking ratios and then manipulating. Many algebraic errors were made, for example forgetting to square the radius.

(d)(i) (SL only) This was surprisingly poorly done. There were many concentric circles drawn, perhaps indicating confusion with gravitational potential. Many radial fields were drawn with the arrows pointing in the wrong direction.

(d)(ii) (SL only) Few candidates scored both marks here. While some realized that the field/acceleration/force would change between points A and B, few realized that g_M signifies g at the surface of Mars only, and that this value would not be appropriate here.

B4 Part 2 (HL) B3 Part 2 (SL) Electric current and resistance

(a)(i) This was generally well done, but many candidates did not state “voltage **across**” or “current **through**” the component.
(a)(ii) Most candidates recognized that the graph was non-ohmic (curved trend line), but did not make the link between gradient and resistance or Ohm’s Law.

(b) (HL) and (b)(i) (SL) No problem with this calculation for most.
(b)(ii) (SL only) Many arithmetic errors were made in this question, in particular with square roots.

(c) Most candidates neglected to realize that the voltage would be split across the two bulbs. They therefore used 6.0 V rather than 3.0 V, and hence read 0.52 A from the graph rather than 0.35 A. Some then compounded the error by doubling their answer as if they had calculated power for a single bulb.

B4 Part 3 (HL only)

(a) Many candidates described a “wave-like nature” for matter but were not specific about all particles having a wavelength. Many still gave the equation with terms defined, however. Many answers referred to just electrons instead of all particles. Examples of particles other than electrons having a wavelength need to be given when teaching this topic.

(b) This question was generally poorly done. Very few candidates related the wavelength of a spectral line to transitions of electrons between energy levels in an atom.

(c) There were some excellent answers, but many candidates did not know where to begin. Some tried a unit analysis but typically did not do well.

(d)(i) This question was generally well done.
(d)(ii) Many candidates were not familiar with the Heisenberg uncertainty equation here.

Recommendations and guidance for the teaching of future candidates

- All candidates must be given the full IB Physics Syllabus and Data Booklet. Both are essential learning tools.

- Candidates should be given many opportunities during the course to practise past papers, and should be given access to markschemes. Many questions appear again and again in similar form and can be practised. For example, question A1 is always data analysis. Some questions, of course, are novel and test the ability to apply knowledge to unfamiliar situations.

- Command terms should be specifically taught to candidates, and they should be trained to respond appropriately to the command term when writing answers. The number of marks available should serve as an indication of the number of points that need to be made.

- Definitions are often so vague that marks cannot be awarded. This type of question is very common and hard work is rewarded. Candidates who compile a glossary of definitions and spend time and energy learning them inevitably do better in this type of question.

- Teachers need to emphasize to candidates that many marks are lost due to incorrect or inadequate descriptions and explanations of physical phenomena. Candidates need to practise this kind of question a lot more than calculations and derivations.

- Working, especially for derivations, or “show” questions, is often so messy as to be indecipherable. Candidates must be strongly encouraged to lay out working in a logical way that shows clearly each step they are taking. Candidates often squeeze answers into the available space, especially if they cross out some work. They should not be afraid to use an extra sheet and use the space to lay out working neatly.

- Although calculations were often done correctly, working was sometimes messy and difficult to follow. Sometimes it takes considerable effort to decipher an answer, even though it may be correct. Candidates should be given clear guidance on how to set out calculations neatly, with a checklist such as:
    - Write down quantities known and unknown
    - Select and write equation
    - Rearrange for unknown
    - Insert known quantities
    - Calculate answer
    - State answer with appropriate significant digits and unit
    - Underline answer or highlight in some way

This would help candidates to clarify their thought processes, and help them to gain marks.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 21	22 - 27	28 - 32	33 - 38	39 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 13	14 - 17	18 - 20	21 - 24	25 - 40

General comments

Virtually all candidates answered exactly 2 options as was required. Most centres clearly teach just 2 options. Those who answered options which were different from the school norm were almost always unsuccessful. The majority of candidates were able to keep their answers within the response box, but the request from some centres to make the boxes larger in size is noted. Overall both papers were, statistically, only slightly more difficult than in May 2011. Almost the full range of marks was seen with the majority of candidates appearing to have sufficient time to complete their answers.

Some of the feedback from teacher's comments on the G2 forms is summarized below.

Higher Level

- 96% of schools responding found the level of difficulty appropriate. 4% of schools thought it too difficult. None thought it too easy.

- 14 of 25 schools thought the paper was of the same standard as last year, 9 thought it more difficult and 2 thought it easier than last year.

- No schools thought the clarity of wording or presentation of the paper was poor. Most thought these were good or satisfactory.

Option I (Medical physics) has grown rapidly in popularity at the expense of options F (Communications) and J (Particle physics). Options E (Astrophysics) , H (Relativity) , and G (Electromagnetic waves) remain the most popular options.

Standard Level

- 94% of schools responding found the level of difficulty appropriate. 6% of schools thought it too difficult. None thought it too easy.

- 61% of schools thought the paper was of the same standard as last year, 31% thought it more difficult and 7% thought it easier than last year.

- 3 schools out of 79 thought the clarity of wording or presentation of the paper was poor. 76 schools thought these were good or satisfactory.

Option A (Sight and wave phenomena) continues to be the most popular option whilst options C (Digital technology) and F (Communications) are chosen by few candidates.

The other options are of similar popularity.

The areas of the program and examination which proved difficult for candidates

All questions are designed to discriminate between the most and least able and as such will necessarily include some more difficult parts. The following are some of the general and specific areas identified as presenting problems to many candidates this year.

- Choosing the appropriate data book formula or equation.

- Knowing what the symbols represent in a data book formula or equation.

- Powers of 10 and unit multipliers continue to pose noticeable difficulty. Often candidates will perform calculations where, for example, mm are used together with m or nm.

- Measurement of stellar parallax.

- Details of the Doppler effect.

- Operational amplifier circuits are not well understood.
- Conversion of eV/MeV/GeV to joules.
- Apparent and absolute magnitudes of stars are often confused.
- Quantitative account of Olbers' paradox.
- Angular magnification applied to the magnifying glass.
- Simultaneity, time dilation, proper length and gravitational red-shift are poorly understood.
- The equivalence principle.
- The units for m and p expressed in MeV/c^2 and MeV/c are difficult for many.
- Feynman diagrams are usually not correct.
- Paying attention to the number of marks awarded for each part question as often candidates provide fewer key facts than is required.
- Careless arithmetic and algebraic errors. (It would benefit candidates if they rearranged an equation first and **then** performed the substitution, showing all of this in a methodical way on the question paper. Many candidates do not seem to work left to right and/or top to bottom. Marks for working cannot be given unless it is clearly presented).

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

The best candidates have clearly seen the syllabus and show good understanding, can manipulate equations, show **all** working in a **methodical** way and explain concepts with clarity. The weakest candidates fail to read the question, have poor knowledge of concepts, lack conciseness and clarity in answers, **do not** show all working or use the wrong equation. Clearly many candidates have studied past papers and are able to show good knowledge of the commonly tested parts of the syllabus. Candidates often perform far better with calculation questions than with questions requiring recall of laws, definitions, experiments and concepts. Weaker candidates may score all of their marks on calculations. Options A,B,D, E, and G at SL and E, H, G and I at HL are very popular and many candidates make a good effort to tackle these questions.

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

STANDARD LEVEL

Option A: Sight and wave phenomena

A very popular option attracting more than 50% of SL candidates

A1. Colour vision

Well done by most candidates, although in (b)ii a significant number made no reference to the graph in their answers.

A2. Standing waves

Part (a) was poorly answered as many candidates could not explain how reflection and superposition led to the formation of standing waves. In (b)ii most candidates gained both marks for velocity but a frequent error was to assume that the length of the string was the wavelength. In (b)iii not all candidates showed both extremes of the standing wave. Although wave velocity is unchanged, in (b)iv many stated three times this value.

A3. The Doppler effect

In (a) marks were lost for no reference to relative motion. Many answers made no reference to frequency and discussed wavelength and (worse) loudness. Part (b)i was well done, the slight red-shift being spotted by most candidates. In (b)ii many found the calculation difficult, using the incorrect formula – often an inappropriate Doppler sound equation. Some of those that used the correct formula used the incorrect denominator.

Option B: Quantum physics and nuclear physics

B1. Plutonium as a power source

In (a) the definition of decay constant was not well known and yet it is frequently tested. Few candidates connected power with activity in (b).

B2. The photoelectric effect

Part (a) was well done. In (b) many were able to do the simple calculations of max electron KE and photon energy; the more able candidates gained both marks but many others gained neither. Many felt the need to convert to joules. In (b)iv the graph drawn often had an incorrect higher saturation current than before.

B3. Electron diffraction

The calculation of de Broglie wavelength in (a) was long and error strewn. Many did manage to get it correct, but often working was scattered all over the response box. Part (b)i was very poorly answered. Those who answered often concentrated on the “shininess” of crystals as good reflectors. In (b)ii quite a few candidates incorrectly interpreted the diagram as analogous to ripples on the surface of water. Few indicated that diffraction is only possible for waves.

Option C. Digital technology

This was not a popular option.

C1. Mobile phones

In (a)i candidates often confused the question with the comparative strength of all the cells with each other rather than for the situation in the question.

Parts (a)ii and iii often produced vague answers without understanding, but in (b) many gave good relevant answers relating to concerns about the use of mobile phones.

C2. Operational Amplifiers (SL and HL)

Very few correct answers seen. But see comments for HL F3.

C3. CDs

In (a)i most candidates could deduce the connection between wavelength and pit depth but could not explain the need for it. In (a)ii the area of the track was difficult for some to calculate. Candidates in (b) could mostly answer the question although some suffered by giving a vague answer.

Option D. Relativity and particle physics (SL and HL questions H1 and J1)

D1. See comments for HL3 question H1.

D2. See comments for HL3 question J1.

Option E. Astrophysics (SL and HL)

E1. See comments for HL3 question E1.

E2. See comments for HL3 question E2.

Option F: Communications (SL and HL)

F1. See comments for HL3 question F1.

F2. See comments for HL3 question F2.

Option G: Electromagnetic Waves (SL and HL)

G1. See comments for HL3 question G1.

G2. See comments for HL3 question G2.

HIGHER LEVEL

Option E: Astrophysics

This was the most popular Option at Higher level, with perhaps 50% of the candidates choosing it.

E1. The star Naos

Although few candidates knew the spectral class of Naos was O, many were able to explain apparent magnitude as a measure of brightness. The calculations in (c) for distance and absolute magnitude were quite well done. There was some confusion between M and m. In (d) very few could give a clear explanation of how the parallax shift, measured at 6 month intervals, was halved to give p. In (e) the luminosity equation had various formulae used for the surface area of a sphere, but Wien's law was generally used correctly. Not many candidates identified the radiation from Naos as largely UV, thus explaining its relative dimness.

E2. Olbers' Paradox

Part (a) was an easy 2 marks for nearly everyone. In part (b) very few candidates paid attention to the need for a **quantitative** explanation of the paradox based on the Newtonian model. Usually the argument given was that an infinity of stars should lead to a bright night sky. In (c) slightly more candidates could explain how the Big Bang model resolves the paradox.

E3. Stellar evolution (HL only)

Candidates were generally familiar with the evolutionary path of the sun in the HR diagram and could explain this in terms of the Chandrasekhar limit - although remnant mass is not well understood. In (b)i some candidates got into difficulty with the proof that star X was 14 solar masses. Most could read off the relative luminosity from the HR diagram, but failed to realize that they just needed to take the 3.5th root of the value. Since this is a “show that” type question all working needed to be visible together with the intermediate answer (13.9) to more than 2 sf.

E4. Hubble's Law (HL only)

In (a)i there were too many candidates who failed to mention recessional velocities of galaxies. Part (a)ii was almost always correct. Many candidates in (b) chose the wrong wavelength as the denominator of $\Delta\lambda/\lambda$ and also failed to note the units of velocity in the Hubble constant. However a good number of candidates obtained the correct answer of 670 Mpc.

Option F: Communications

Fewer than 10% of candidates chose this Option.

F1. Radio transmission and reception

Candidates could usually find the frequencies and bandwidth in (a) i,ii,iii. However in (a)iv the mathematics proved too difficult for most or they did not know what to do with the relative power formula. In (b) the AM receiver question was done quite well, but many candidates were careless in identifying the AF amplifier. The advantages and disadvantages of AM transmission compared to FM seem to be well known.

F2. Analogue signals

Parts (a) and (b) concerning signal sampling were done well although in (b)ii quite a few candidates did not give binary numbers. In (c) candidates often struggled to organize their thoughts in explaining time-division multiplexing.

F3. Operational amplifiers (SL C2)

This proved to be a difficult question. In (b) the proof of the gain formula was poorly done with many candidates unaware that the currents in the resistors are ideally the same and that v+ = v-. In (c) some candidates assumed incorrectly that it was still a **non-inverting** amplifier, but many could calculate the correct gain.

Option G: Electromagnetic Waves

Approximately 40% of HL candidates chose this option.

G1. The magnifying glass

Hardly any candidates could define angular magnification properly in terms of the near point. In (a)ii very few could derive the specific formula for the angular magnification of a magnifying glass with an image at infinity. However in (b) nearly all candidates scored an easy 4 marks using the lens formula. This indicates that whilst linear magnification is easily understood the reverse is true for angular magnification.

G2. Lasers and diffraction

Most candidates could identify a laser as producing coherent and monochromatic light. In (a)ii only about half of them could explain the production **mechanism** in terms of 'pumping', population inversion, metastable state, simultaneous transitions, etc. In (b)i a few candidates could remember seeing a demonstration of the line of red dots obtained when a laser is passed through a diffraction grating. In the calculation of laser diffraction in (b)ii very few candidates could determine the grating spacing in metres from the 600 lines per mm given. Power of ten errors were common and ECF (error carried forward) was applied to many answers.

G3. X-rays (HL only)

The explanation of the characteristic lines of an X-ray spectrum is a frequently tested part of the syllabus. A disappointing number of candidates could identify the 3 main steps of inner shell electron ejection, followed by electron transition from a higher level with emission of a specific X-ray photon. In (a)iii most candidates used the correct formula for minimum wavelength, but often failed to convert keV to joules. Candidates often overlooked the fact that interference had any part to play in X-ray scattering in part (b)i. In the calculation of crystal plane spacing in (b)ii some candidates forgot the 2 in the Bragg equation. Of course ECF was applied when double the correct answer was given.

Option H. Relativity

Almost 50% of HL candidates chose this Option.

H1. Relativistic kinematics (SL D1)

In (a) nearly all candidates could identify T as obtaining the proper time, but often stated that it was because the clock was in the same frame of reference as T. The clock is in everybody's frame of reference. However to record proper time it must be at a fixed point in space/at rest – which it is in T's frame but not in G's frame. γ calculations are usually done well. In (c) very few candidates show an understanding of simultaneity and often explain events from the wrong frame of reference. In (c)ii there was often irrelevant mention of G 'seeing' the lightning. The question does not ask about the arrival of the light at G. In (d) (HL only) most could find the length contraction of the train observed by G (50m), but not the spacing of the marks on the ground (512m) which is a proper length for G that T sees contracted to 160m. Most candidates could apply the velocity addition formula in (e) (HL only), but inevitably there were errors with sign convention giving either velocities of zero or >>c.

H2. Relativistic mechanics

Although question (a) refers to the measurement of the speed of the photons, many candidates answered in terms of the pion only. The photons both had speed c of course. In (b) about half of all candidates could calculate the energy and momentum of the pion correctly, but the others were confused by the units of mass and momentum involving c. Most candidates stated that photon R had greater energy in (b)iii but did not get the second mark for an explanation in terms of momentum conservation. Sadly many stated that photon R moved faster than photon L.

H3. The equivalence principle and black holes

Candidates often produced garbled versions of the equivalence principle. There are many versions and they only have to learn one. In (b) most candidates could calculate the frequency shift, but about half then incorrectly **subtracted** the value from f. The observed reduction in frequency (red-shift) of light as it climbs a gravitational well was often mentioned in (b)ii but not the link to the correspondingly shorter time period lower down the well which represents the gravitational time dilation. Virtually every candidate could attempt a different sensible statement of the meaning of a black hole, but there were some very imaginative answers for how to detect one. Gravitational lensing and radiation from matter accelerating into a black hole were, however, often mentioned.

Option I: Medical Physics

This Option is becoming more and more popular, with about 40% choosing it.

I1. Hearing

A few candidates in (a) think that the threshold of hearing is to do with minimum or maximum audible frequency. The calculations involving sound intensity in (b) were well done by the majority, but it should be noted that when an answer is given the full working is expected in the calculation. Part (c) was generally well done, although reading the log scale for f was difficult for some. In (c)iv the curve for an elderly person needed to be higher and have a reduced range and was usually correctly drawn.

I2. Ultrasonic imaging

Part (a) was poorly answered. An AC potential at the crystal's resonant frequency > 20kHz was almost never mentioned. Part (b), concerning acoustic impedance, was answered more or less correctly by the vast majority of candidates.

I3. Therapeutic radiation

In (a) candidates who merely repeated the question by referring only to diagnosis and therapy scored zero. Better answers usually mentioned radiation imaging and radiotherapy treatment. Very few candidates in (b) could clearly explain the meaning of quality factor. In (b)ii there were some good attempts at the calculation for absorbed dose rate, but ECF often had to be used for failure to work in seconds or making power of ten errors. There were some sensible and not so sensible answers to part (c) – with many candidates repeating themselves in 3 different ways in saying that radiation can have side effects.

Option J. Particle physics

This is the least popular option with fewer than 5% of HL candidates choosing it.

J1. Quarks and interactions (SL D2)

(a) Exchange particles were not usually well explained as bosons which mediate forces/ interactions. Knowledge of sigma decay was not needed to successfully answer part (b) and some correct answers were seen. The command term “determine”, in part (c), has a specific meaning and required an explanation together with the statement that strangeness is not conserved. In (d) the unit GeV was often not converted to joules. The Feynman diagram was very poorly drawn, usually with the wrong boson (should be W+) or the wrong fermions, even though all four of these are given.

J2. Particle accelerators

It was clear from the few answers to (a) that the synchrotron is not well understood by the majority of candidates although a few did mention synchrotron radiation in part (a)iii. 60 GeV gained an easy mark in (b)ii. In (c)i the calculation of available energy was done very poorly as candidates often did not know the symbol meanings in the data book equation. Part (c)ii was found difficult, especially if the answer to part (c)i was wrong.

J3. Conservation laws and the standard model

In (a) candidates often failed to name specific particles (muon neutrino, electron antineutrino). The role of the Higg's boson was generally known.

J4. The early universe

Part (a) found most candidates guessing. Part (b) was also poorly answered. Those that attempted it often did not convert eV to joules.

J5. String theory

Differences between string theory and the standard model were correctly stated by most candidates.

The type of assistance and guidance that teachers should provide for future candidates

The option topics allow candidates to experience some of the more challenging and interesting areas of Physics. However the importance of the fundamental principles of the subject should not be underestimated. Definitions and statements of laws are often poorly expressed or unintelligible. In general candidates tend to perform less well on the descriptive parts of questions and these are often the cause of the difference between a mediocre and good grade. Past question papers provide the opportunity for essential practice with the style of questions candidates will face. Giving candidates model answers (as well as past markschemes) can be very helpful. The marking of key phrases in a question should be encouraged as so often an instruction or piece of information is missed.

All candidates should be given the full IB Physics Subject Guide and Data Booklet. Both are essential learning tools and very useful as revision checklists. The subject guide can be annotated with textbook page references and past paper question references. Teachers need to have sessions during revision to explain the use of every equation and all items of data in the Data Booklet.

Hyperphysics, CERN, NASA, Physics.org, outreach.atnf.csiro.au, phys.unsw.edu.au, etc. provide a wealth of online sources of information that can be organized by teachers into a very valuable learning tool to supplement textbooks in the teaching of each of the options.