Physics, Timezone 2

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 29	30 - 41	42 - 51	52 - 62	63 - 71	72 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 26	27 - 38	39 - 48	49 - 58	59 - 68	69 - 100

Higher 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

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

General comments

The IA moderation for the May 2014 exam session proceeded with no significant difficulties. The majority of centres performed established assessment investigations and provided detailed assessment comments and notation. This was most helpful to the moderators. The majority of candidate reports were word-processed and graphs were drawn with graphing programs.

The range and suitability of the work submitted

Most centres had a comprehensive practical program and teachers were assessing appropriate work. However, more and more centres are assigning only two investigations for assessment, and this limits the candidate's chances of earning higher marks. There was wide use of ICT and many traditional labs are being carried out. One trend unique to this exam session is that a few centres were assigning computer simulations for a three criteria assessment lab. Although using a simulation is not forbidden candidates and teachers must be very careful to ensure that the chosen simulation can achieve the aspects of the assessed criterion.

Candidate performance against each criterion

Design (D)

Most centres are using established design prompts. In a few cases, however, the prompts were not appropriate because the teacher gave the candidate a relevant formula and the independent variable. Good design prompts are ones that have candidates looking for a function between two variables, not a specific value like gravity or the specific heat capacity of an unknown liquid. Candidates need to be reminded that for a complete under design that variables need to be defined (and vague statements like "I will measure the time" needs 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. Design is not a research or textbook based activity.

Data Collection and Presentation (DCP)

Candidates earned the highest marks under the DCP criterion. 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. Presenting data on graph is expected and indeed required for full assessment under DCP.

Conclusion and Evaluation (CE)

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. Teachers need to look for this when awarding aspect 1 a complete, as many times moderators had to change a 'complete' to a 'partial'. CE is best assessed when candidates also have designed and performed the investigation themselves. Many candidates construct two parallel columns corresponding to CE aspects 2 and 3. This helps the candidate make their ideas clear.

Recommendations for the teaching of future candidates

Many centres are allowing candidates only two opportunities to earn their best marks. It is recommended that after candidates become familiar with the expectations of IA, that they have a number of opportunities to be assessed, perhaps 3 or 4 from which the highest two of each criterion are used for their IA mark.

Because the IA mark is part of the candidates overall IB grade, it is important that candidates work on their own. They must collect their own data, decide on how to process it and write the report on their own. Group work is not allowed although candidates can help each other with the physical manipulation of equipment.

Although many centres correctly appreciate errors and uncertainties, this remains one of the weaker areas for some other centres. Teachers need to address the appropriate treatment of uncertainties in lab work, especially when expressing the gradient and its uncertainty for linear graph lines.

Teachers should bear in mind that it is often too difficult to come up with improvements for well-established, traditional experiments for assessment of CE. For this reason, candidates should not be assessed for CE when performing a traditional and established high school investigation.

Further comments

Teachers must assign appropriate tasks when assessing IA. Only a few centres failed to appreciate this and the marks for these centres were adjusted. Teachers are reminded that a design investigation is not meant to be research project, that under design no hypothesis is expected, and that the teacher must not suggest the independent variable to the candidate.

The following 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.

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 labelled 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.

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.

When moderators do not mark down

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

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.

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 this minor error down. 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 manufacture's claim of accuracy, but this is not required. When raw data is processed, uncertainties need to be processed (see the Subject Guide, assessment statement 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.

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. Yes, this does mean that candidates could get high DCP marks for quite brief work on limited data but, if they have fulfilled the aspects requirements within this small range, then the moderator will support the teacher’s marks.

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). It is difficult to earn a complete in CE (aspect 1) because serious and thoughtful comments are required, something beyond “the data reveals a linear and proportional relationship”.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 15	16 - 20	21 - 23	24 - 27	28 - 30	31 - 40

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 13	14 - 16	17 - 20	21 - 23	24 - 30

General comments

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

Every year there are occasional comments from teachers that either paper 1 or paper 2 are unbalanced in terms of syllabus cover. It should be noted, however, that these two papers together aim to provide valid assessment of the complete syllabus, both in content and skills. The specific skills that need to be encouraged 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 112 responses from 806 centres and for HL there were 153 responses from 776 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.

The replies received indicated that the 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 and generally in line with last year's papers, although 33% found the HL paper (but only 17%% the SL paper) more difficult than the May 2013 paper.

With few exceptions, teachers thought that the presentation of the papers and the clarity of the wording were either satisfactory or good. There were some comments to the effect that some of the questions were too wordy for second language candidates.

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.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	560	4568	844	494	14	70.49	0.48
2	378	102	4253	1737	10	65.63	0.47
3	165	3775	2017	513	10	58.26	0.37
4	1009	379	1136	3928	28	60.62	0.29

5	1353	3158	1313	640	16	48.73	0.47
6	4160	717	1227	335	41	64.2	0.52
7	1018	3770	1059	595	38	58.18	0.5
8	2973	1403	642	1452	10	45.88	0.43
9	840	130	242	5261	7	81.19	0.32
10	941	396	140	4997	6	77.11	0.28
11	4657	703	495	616	9	71.87	0.38
12	1525	2259	1459	1205	32	22.52	0.1
13	4374	911	533	646	16	67.5	0.53
14	638	447	283	5095	17	78.63	0.42
15	1291	3418	1060	689	22	52.75	0.54
16	696	3712	1647	408	17	57.28	0.43
17	1079	1609	2988	788	16	46.11	0.36
18	2931	689	2518	285	57	45.23	0.44
19	3460	878	475	1617	50	24.95	0.11
20	221	974	2320	2960	5	35.8	0.26
21	881	1504	2422	1644	29	37.38	0.28
22	1170	156	4680	465	9	72.22	0.28
23	316	1321	681	4140	22	63.89	0.45
24	420	4648	280	1086	46	71.73	0.28
25	2024	3368	948	97	43	51.98	0.46
26	5417	188	472	397	6	83.6	0.21
27	449	5434	551	41	5	83.86	0.29
28	975	918	1593	2971	23	24.58	0.07
29	1144	2344	1255	1689	48	36.17	0.46
30	4562	258	107	1535	18	70.4	0.52
31	1632	695	656	3467	30	53.5	0.5
32	2680	958	2527	282	33	41.36	0.52
33	3383	875	1594	596	32	9.2	0.07
34	174	5974	280	40	12	92.19	0.18
35	811	985	2187	2441	56	37.67	0.33
36	1590	486	3676	701	27	56.73	0.29
37	4422	172	727	1135	24	68.24	0.44
38	188	619	711	4928	34	76.05	0.35
39	688	1704	1267	2704	117	41.73	0.53
40	783	713	4615	337	32	71.22	0.44

Number of candidates: 6480

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	624	2827	1095	542	10	55.45	0.55
2	320	1359	1050	2355	14	46.19	0.59
3	532	207	2796	1560	3	54.85	0.46
4	207	2581	1931	374	5	50.63	0.33
5	951	393	1041	2707	6	53.1	0.32
6	3277	1176	371	267	7	64.28	0.38
7	2585	1629	456	407	21	50.71	0.38
8	584	109	4224	172	9	82.86	0.28
9	1096	1030	1097	1860	15	36.48	0.33
10	918	152	309	3714	5	72.85	0.47
11	1172	551	235	3135	5	61.49	0.38
12	1143	1635	170	2146	4	32.07	0.42
13	2710	950	678	747	13	53.16	0.52
14	871	482	640	3093	12	60.67	0.66
15	891	2800	694	698	15	54.92	0.37
16	153	2323	944	1671	7	45.57	0.53
17	326	1223	1364	2176	9	26.76	0.28
18	777	1244	1723	1343	11	33.8	0.29
19	1316	630	887	2252	13	44.17	0.47
20	1512	365	2709	500	12	53.14	0.42
21	312	1420	832	2513	21	49.29	0.48
22	3364	531	661	531	11	65.99	0.56
23	679	3562	775	66	16	69.87	0.44
24	446	1331	2532	767	22	49.67	0.39
25	355	4243	452	42	6	83.23	0.3
26	1148	839	1750	1331	30	26.11	0.34
27	1254	343	2791	684	26	54.75	0.28
28	1193	307	2547	1008	43	49.96	0.5
29	2751	236	818	1270	23	53.96	0.51
30	1423	1909	254	1483	29	27.91	0.33

Number of candidates: 5098

Comments on the analysis

Difficulty

The difficulty index varies from about 9% in HL and 26% in SL (relatively 'difficult' questions) to about 92% in HL and 83% in SL (relatively 'easy' questions). The papers gave an adequate spread of marks while allowing all candidates to gain credit.

Discrimination

All questions 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, then an educated guess should be made. In general, some of the ‘distractors’ should be capable of elimination, thus increasing the probability of selecting the correct response. If candidates concentrate on selecting the correct response – instead of working out the correct answer (as they might in paper 2) then there should be adequate time to complete all the questions and check the doubtful ones.

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

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, that is, those that illustrate a particular issue or drew comment on the G2’s.

SL and HL common questions

SL Question 4 and HL Question 3

There were some comments from teachers that candidates should not need to count squares. However, dropping a vertical from the reaction arrow and continuing the friction line backwards would reveal both C and D as incorrect.

SL Question 5 and HL Question 4

Candidates are often under the misapprehension that there are conditions upon Newton’s third law. It should be stressed that it is always true irrespective of energy or momentum considerations; and it does not depend upon the state of motion of the bodies in contact.

SL Question 11 and HL Question 10

Candidates are required to learn definitions. There are conditions (such as changing pressure) where the temperature of a body changing phase may alter. If this is the case then the specific latent heat does not apply.

SL Question 17 and HL Question 20

Many candidates were distracted by D and there were quite a few comments from teachers suggesting that this should be accepted. But D is not true as in most cases the varying current will change the temperature of the wire causing a change in resistance. It is only true in the case that temperature is kept constant – and that is the correct statement of Ohm's Law. C is an alternative statement of Ohm's law, given that resistance is calculated from V/I in any particular situation.

SL Question 18 and HL Question 21

As these are identical lamps we can assume that their brightness depends either on the current through them or on the voltage across them, whichever is easier to find. (Note that if they had been non-identical lamps, then we would have had to find the power, VI, to detect the brightness).

Opening the switch will increase the total resistance of the circuit, reducing the current through W. Hence B and D can be eliminated. And opening the switch will also increase the voltage across Y – from about V/3 to V/2. Hence C.

SL Question 20 and HL Question 22

This is another case where candidates are required to learn a definition and identify it accurately.

HL Questions

Question 5

Candidates should understand technical language such as 'dissipated' even if they are working in a second language.

Question 6

This is a perfect example of a question that can be 'seen' without any calculation. If θ is zero the height will be zero – so it is either A or C. From consideration of the units, C gives a time (in seconds) so must be discounted.

Question 8

Candidates are required to give the best answer. A is possible, but more importantly, B, C and D are patently incorrect to anyone who knows what an equipotential is. Hence A must be selected.

Question 11

There are two changes that are made in going from X to Y. A simple sketch, done while reading the stem, should show which way the proportionality works. As there are no squares in pV = nRT, the answer must be A.

Question 12

There is evidence of much guessing in this question and it elicited a few adverse comments from the teachers. But both A and B are logically equivalent so must be wrong. As an adiabatic expansion involves no thermal exchange with the surroundings, this will not affect the entropy of the local surroundings. Hence C must be correct by elimination.

Question 18

It is logical that as D increases so the width of the central maximum will increase. Hence B and D (both with D on the denominator) can be eliminated. A sketch of the graph of the diffraction pattern for a single slit will show that A is correct.

Question 19

This was very poorly done with over half of the candidates opting for A. Simple recall of the Brewster angle, which involves tan of an angle, should cause candidates to eliminate B and C (which most of them did). To choose between A and D, though, it is required to look at the situation as depicted (rather than jumping to conclusions based upon familiar diagrams). θ is the angle to the surface – not the angle of incidence. So A must be incorrect.

Question 28

This question did involve careful reading. The statistics would suggest that many candidates rushed the question and guessed the answer. The question was not asking which of the statements was true – but rather which of them showed that light consists of photons. Clearly I will be true if light is either a wave or photonic, so D, the most popular answer, must be incorrect.

Question 29

This was a very good discriminator – but involved a lot of guessing for the weaker candidates.

Candidates should be familiar with the de Broglie wavelength increasing as the speed of the particle increases, so C and D can be eliminated immediately. And, in calculating the change in wavelength (which they do not need to do) the equation kinetic energy = potential energy will be used. This involves the square of the velocity, hence B must be true.

Question 32

C was a popular, yet incorrect, response. Candidates need to know that the nucleus has its own discrete energy levels, which are revealed in the emission of a ɣ-particle.

Question 33

Well over 50% of the candidates chose A and seemed unaware that if we say that an element has a 'very long half-life' then we are, in all likelihood talking about timespans that far exceed the length of a human life. Hence it is not possible to come back later and hope to see a noticeable diminution of the activity of the sample. The syllabus guide clearly invites teachers to consider how to measure very long half-lives and this can only be done without reference to time. Hence it must be D. Note that the stem does specify that the sample is pure.

SL Questions

Question 9

There was much guessing here with even A and C being popular options. This would suggest that many candidates had not understood the situation – surely a fly near the hub of spinning bicycle wheel is going slower than one perched on the rim. So A and C should have been instantly discounted through the application of commonsense. Since the velocity and also the radius is changing from situation X to Y, it is easier to use the formula a = ω2r (where ω is constant) to ascertain that the acceleration at Y is greater. Alternatively, you can imagine that Y is on the outer edge of a fairground big wheel in order to realize that the forces upon you (and hence acceleration) will be greater.

Question 12

The weaker candidates were opting for D. But D does not answer the question which asks for an explanation for the temperature rise.

Question 15

The quartz oscillator is explicitly mentioned in the guide (4.3.6). But even a holistic understanding of the role and nature of damping would lead to the elimination of A, B and C – all of which the candidates should be familiar with.

Question 24

Many candidates opted for B, presumably assuming that a neutron had no mass.

Question 30

It is a frequent misunderstanding, borne out by the statistics, that the ozone layer somehow plays a significant role in global warming.

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 practiced, a paper at a time, solely for the final examination session.

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 90^0 will show which is correct.
- Use proportion: new quantity = old quantity x a fraction, where the fraction depends upon the variables that have changed.
- 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, 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 (March 2007) during preparation for the examination, in order to clarify the requirements for examination success. Teachers should be aware, that questions are constructed from the requirements of the syllabus – not from previous papers!

This Guide does invite the candidates to recall certain simple facts, although most of Physics is process orientated. 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 tested and learned 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. Ample time should be apportioned to the teaching of such topics as Global Warming and the Greenhouse Effect in a rigorous fashion based upon physics. The common knowledge that most people have about these areas of the Guide is not always sufficient to answer questions on these topics, 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 - 32	33 - 41	42 - 51	52 - 60	61 - 95

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 12	13 - 17	18 - 22	23 - 27	28 - 50

General comments

183 HL and 143 SL sets of G2 comments were received from centres. The G2 comments suggested that some centres found that this paper was harder than that of the May 2013 session. Presentation and wording were generally regarded as adequate.

Candidates have sometimes only superficial understandings of the tested concepts. Candidates may have a reasonably robust grasp of theory but when faced with a practical context they are not able to apply what they have learnt. Candidates were expected to be able to convert between units and they could not do this fluently. Explanations were poor, as seen in previous examinations. It is clear that candidates must take more time when they read questions. Much work goes into devising questions that contain virtually no superfluous information; paper authors try to make every word count.

The presentations of many calculations consisted of a jumble of arithmetic with numbers usually appearing out of nowhere. Candidates need to be aware that their answers should read logically well. Only in this way then can compensatory marks be awarded for incorrect answers.

There was no evidence that candidates were under time pressure in this examination. There were few blanks towards the end of the papers.

Presentational skills continue to be lacking in many candidates. It is a cause for concern that so many express themselves so badly in words, mathematical symbols, and diagrams. We know that the candidates produce significant pieces of writing for their other IB diploma subjects but these skills are not transferred.

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

- Knowledge and use of, and conversion between, simple energy units
- Written and mathematical statements of Newton’s laws and deductions from them
- Quotation of “standard” definitions, for example mass defect and magnetic flux
- Drawing and annotation of a binding energy per nucleon graph
- Understanding of the relationships between gravitation potential, potential energy and kinetic energy for a satellite
- Extended calculations of mechanical systems in an unfamiliar context

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

- Thermal energy calculations and thermodynamic explanations
- Understanding of internal resistance and associated calculations

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

Section A

1 [HL and SL] Data analysis question

(a) Most candidates understood the requirements of the question. They were able to draw an acceptably smooth curve extrapolated to the time axis. There were fewer poor quality lines than in previous examinations. Nevertheless, a substantial minority ended the curve at a time of 08:30 and then quoted this time as that at which the solar panels began to generate energy. Some drew a straight line (that could not possibly touch all the error bars) and extrapolated this line to a time of about 07:30. Some credit was available for this.

(b) This was poorly done from two points of view. It was clear that there was widespread misunderstanding of the relationship between energy and power units. Many candidates could get no further forward than calculating the energy used by the house in the four-hour time period. Most were unable to recognise that the energy supplied to the grid was related to the area under the graph.

(c) Candidates were usually able to read the error bar as having a total length of 0.8 units and could use this to calculate the uncertainty in P. Some were able to work through to the correct answer but many made a sign error in the calculation.

(d) A number of past data-analysis questions have asked for a simple statement of the proportionality or otherwise of a provided graph. The use of the command verb “determine should have indicated to student that this question required more. The full relationship was required for full marks. For example, a determination of the gradient and the intercept (or solution from data points) to yield the equation relating P and t for the graph.

2 [HL & SL] Energy

(a) Many candidates scored at least two marks on this straightforward recall of material from the syllabus. In weak answers it was not always clear that the statements of energy referred to molecules, atoms or particles in the solid or liquid. There was also confusion as to whether the melting process involved an increase or decrease in potential energy.

(b) The calculation was well done by many with substantial numbers of correct answers. A common error was a failure to read the units of specific latent heat of the zinc correctly and thus to incur a power of ten error. This lost some though not all of the marks. Solutions that incurred zero or a low score were characterised by ill-presented and unexplained numbers showing that the candidate had little idea of the correct approach to the problem. Examiners expected the answer to this question to begin with “Energy lost by zinc = energy gained by iron” and to proceed step by step from there.

3 [HL & SL] Binding energy and mass defect

(a) Most were able to define mass defect correctly but there were many small slips that denied the mark. Candidates should be encouraged to learn definitions or to understand the physics lying behind the definition sufficiently well to construct the definition from scratch. Candidates often compared atomic masses with the sum of the nucleons without commenting on the role of the electrons. Some definitions were in terms of energy. Others simply said that the mass of a nucleus is reduced when constructed from the individual nucleons, without answering the question.

(b)(i) This relatively easy problem was not well done. There were many permutations of the numbers, and almost all were poorly explained. Completely correct solutions were rare and even these tended to have a poor level of explanation.

(b)(iii) Candidates are required to be able to draw and annotate this plot. This question proved that very many do not appreciate the prominent features. There were mis-drawings on both sides of the maximum; the maximum itself was often misplaced by more than the specified tolerance (showing that candidates do not appreciate the minimum value of the binding energy per nucleon at the Fe-56 or Ni position). Other errors included inappropriate gradients on the right-hand side of the graph compared to the left and failures to begin the curve at the correct place.

(b)(iv) Few candidates referred their knowledge to the graph and simply recalled – often correctly – some physics about the stability of the fusion product. However, this was rarely referred to the relative position of reactants and product on the graph.

4 [HL only] Waves

(a)(i) Most candidates were imprecise in their descriptions of the direction of motion of the air molecule. Very many think that the conventional diagram for the standing sound wave in a gas shows that the molecules move between the drawn lines of the wave. Answers such as "vertical" were common. Other inadequate responses featured "to the right" without the candidate realising that this implies that a molecule moves continually to the right eventually leaving the tube.

(a)(ii) Descriptions of the amplitudes at P and Q were better but for a minority of candidates there was confusion between the meaning of node and antinode.

(b) Calculations were generally well done.

(c) This question was an "outline" and required a more sophisticated approach than "it is caused by the Doppler effect". Examiners were looking for a description of the causes of the change in wavelength as perceived by the moving observer. Explanations that quoted a Doppler equation (it had to be the correct one) and deduced an increase in frequency were not awarded full marks as this is little more than copying by rote from the data booklet.

(d)(i) Many forgot that the image separation has to be twice the pixel length. Others inverted the magnification equation. A large number of one mark solutions were observed with only perhaps 50% of the candidates gaining full marks.

(d)(ii) Again, careless slips denied many full marks even though this well-rehearsed examination question appeared to be understood by many.

5 [HL only] Generating emfs

(a) A strong and complete definition was required here. It was often lacking. There were references to "magnetic field" or "magnetic strength", and the angle between B and θ was often incorrectly defined. This standard bookwork left a lot to be desired.

(b)(i) A standard error in this calculation was to misunderstand how to determine the speed of the rod. Some credit was allowed if this was incorrect. Many candidates recognised that the emf was related to *Blv* and the speed determination was their only error.

(b)(ii) Space had been left on the graph for two complete cycles of the wave and this is what examiners expected to see. Very many candidates failed to think the problem through and assumed that the grid axes had been set up for one period. Most candidates realised that there was some sinusoidal behaviour for the emf. However, examiners saw a minority of very strange graphs.

Section B

6 [HL] & 4 [SL] Renewable energy sources

(a) Many candidates continue to give weak responses to questions in which they are asked to compare renewable and non-renewable resources. Although the “it cannot be used again” answer has largely disappeared, many candidates still fail to appreciate that the issue is about the rate at which the resource can be replaced.

(b)(i) This was often well done, although occasional recourse was made to inappropriate physics (see bii). Candidates should note that in questions where the final answer is quoted (typically “Show that …..” questions) candidates are strongly advised to quote answers to one more significant figure than in the question.

(b)(ii) The rare candidate who understood the physics here was able to give a clear account of the solution. Many failed to spot the factor of a half in the water level change and introduced a factor of two later and arbitrarily. Others completely misunderstood the (simple) nature of the problem and used a random equation from the data booklet (usually $1/3\rho Av^3$). This of course gained no marks. A simple initial diagram would have helped many to avoid errors.

(b)(iii) As in question 1 there were far too many candidates who clearly do not understand and have not practised the problem of converting between energy units. Effective use of units would have made this an easy calculation. Explanations were few and candidates were clearly struggling with this aspect of energy.

(c)(i) Many candidates were able to give one coherent reason but two distinct answers were rare.

(c)(ii) Many candidates either described the greenhouse or the enhanced greenhouse effects without reading the question. What was required was a consideration of the effect of changes in Earth temperature on (for example) the amount of ice coverage. Consequently examiners observed low marks for what should have been a straightforward question.

[HL only] Gravitational potential of the Earth

This question taken as a whole reveals how poorly candidates understand the relationships between field quantities. There is no evidence that this is confined to gravitational work as past examination questions have revealed misunderstandings surrounding electric fields too.

(d) This was a simple test to establish whether candidates could check the consistency of data. Most could not. The obvious solution (to evaluate Vr twice having first incorporated the radius of the Earth) was rare. Many candidates preferred to calculate the mass of the earth twice and check that the values obtained were similar. In principle this could have scored full marks but three marks were only rarely seen by examiners.

(e)(i) It is quite clear that candidates do not understand the relationship between gravitational potential and gravitational potential energy. A consideration of units could have led them in the correct direction. Many could only tackle this by carrying out a full solution from the gravitational potential equation printed in the data booklet.

(e)(ii) Similarly candidates were unable to use the known change in gravitational potential energy to establish the change in kinetic energy. Most felt that they had to calculate the kinetic energies from first principles and usually obtained the wrong answer.

(e)(iii) Most candidates did not continue from (i) and (ii) to this part question; it was either left blank or an attempt was made at a statement of conservation of energy. This was another case where knowledge of a principle does not necessarily mean that a candidate can operate it effectively. Even the most able candidates seemed to struggle with this standard piece of bookwork.

[SL only]

4 (d)(i) As is often the case with this question, candidates state that "momentum is conserved" and fail to explain what this means. There was much confusion with energy conservation rules.

4 (d)(ii) Calculations of the final speed of the neutron were confused with little or no explanation of the equations. It was often not clear what mass values (if any) were being used in the solution.

4 (d)(iii) There were few clear solutions to this problem. Some candidates did not appreciate the meaning of fractional energy change and others were still travelling along the momentum route from an earlier part, scoring few, if any, marks.

4 (d)(iv) Candidates had evidently not considered the mechanical issues of moderation in their learning. There was little recognition that the change in fractional energy is 0.33n where n is the number of collisions. The most frequent answer was that the change is 0.33n.

4 (d)(v) There was more clarity about the reasons for moderation but even so, answers were poorly expressed. Only a minority recognised that the probability of absorption is greatest at low neutron incident energy.

7 [HL] & 5 [SL] SHM and sound

This was an example of an extended question in an unfamiliar context to candidates. Those who chose this did well and were able to apply their physics without difficulty.

(a) It was rare to see all four marks awarded for statements of the requirements of harmonic oscillation and recognition of these in the straight-line graph. Candidates were generally happy to state that acceleration is directly proportional to displacement and that the straight line through the origin confirmed this. Correct statements with appropriate detail of the direction of the force/acceleration were rarer and the negative gradient was not often mentioned. Four marks were available and therefore candidates should have recognised that four points were required.

(b) At SL this calculation was poorly done. HL candidates were better, often giving good detail and confirming the correct answer convincingly.

(c)(ii) P – when it was marked on the graph at all – was either shown at the origin (correct) or one extreme (incorrect) of the graph in about equal numbers.

(d)(i) Candidates are required to know the relationship between wavefronts and rays and it was surprising that many completed the diagram with wavefronts – and even these would not have gained much credit given the very poor draughtsmanship in evidence. Few candidates bothered to read the question. They failed to realise that all they were required to do was construct plausible incident and reflected rays that would enable the observer at point 1 to hear the sound.

(d)(ii) There were many examples of correct evaluation of the wavelength of the sound but far too many were unable to complete this simple task. Inversions of the equation and mistakes in powers of ten and in rounding were common.

(d)(iii) The usual phonetic spelling of “defraction” was observed. Examiners are unlikely to give a benefit of the doubt to what might have been a phonetic spelling or might equally have been confusion with “refraction” in this particular case. Many candidates were able to spot that the sound was being diffracted but an explanation of what diffraction is, in context, was much rarer.

(e) By contrast, many were able to express themselves well both about the nature of the interference and the path/phase difference that must have given rise to it. It was rare to see the fourth marking point awarded as few candidates read the question carefully enough to be able to explain why the amplitude of the sound is small rather than zero.

(f) [HL only] Many were able to quote an example of an analogue audio storage device. Fewer read on in the question and were able to give a brief account of how it worked. Such accounts were limited.

(g) [HL only] Many candidates answered the question that they thought had been set rather than the one actually posed. Many wrote at length about the conversion of light rather than focussing on the stages that occur after the charge has been released in the pixel. It was rare to see a consideration of the conversion of the analogue potential difference value to a digital form.

[SL only] Electric and magnetic fields

5 (e) [SL only] Superficial answers were common. Candidates continue to ignore the mark allocations for questions and therefore the number of independent points they should mention in an answer. Here, most said that conductors contain free electrons (or the reverse for insulators) but did not go on to discuss the role of the free electrons in carrying charge or to

relate the current to the existence of an electric field across the conductor. Far too many gave answers of the “conductors conduct well” variety that do not score marks.

5 (f) [SL only] There are three elements to a good drawing of the magnetic field around a long straight conductor: the concentric circularity of the lines, the direction of the lines related to the direction of charge flow, and the increasing separation between lines as the distance from the conductor increases. It was a rare candidate who was able to convince the examiner with all three points. In hindsight, the diagram could have been larger on the page. However, candidates could have taken more trouble over their sketches which were usually crude.

5 (g)(i) [SL only] Many forgot that the sign rules involve conventional current and lost the mark.

5 (g)(ii) [SL only] Few correct solutions were observed. This was a straightforward problem involving one re-arrangement of a standard equation and the incorporation of the weight of the conductor.

8 [HL] & 6 [SL] Electric cells

(a)(i) [HL only] Superficial answers were common. Candidates continue to ignore the mark allocations for questions and therefore misunderstand the number of independent points they should mention in an answer. Here, most said that conductors contain free electrons (or the reverse for insulators) but did not go on to discuss the role of the free electrons in carrying charge or to relate the current to the existence of an electric field across the conductor. Far too many gave answers of the “conductors conduct well” variety that do not score marks.

(a)(ii) [HL only] Too often candidates were content to suggest that the internal resistance of a cell is the resistance of the cell contents without discussing the physical implications of this. It was rare to see a consideration of the energy dissipation in the cell or an explanation of the way the power loss is related to a “resistance”.

(b)(i) [HL] & (d)(i) [SL] Circuit diagrams continue to be a particular issue for many candidates. Neat, well-drawn diagrams are rarely seen. Some diagrams had two cells, the lemon cell and another. Variable resistors were sometimes absent (or were drawn as fixed). Potential dividers were often attempted usually unsuccessfully. Generally candidates gained an average one mark for what should have been a familiar task.

(b)(ii) [HL] & (d)(ii) [SL] Those who quoted the data booklet equation and the definition of resistance were generally able to show the final expression. Some however could not convince the examiners that they knew what they were doing.

(b)(iii) [HL] & (d)(iii) [SL] Candidates were expected to understand the physical point that the emf can be determined when the current in the cell is zero. For many, an extrapolation of the obvious straight line to the emf axis and a correct read-off gave an easy couple of marks. Some however did not understand the physics of the circuit and gave poorly described solutions.

(b)(iv) [HL] & (d)(iv) [SL] The internal resistance was best obtained from a large triangle drawn on the graph. Many however gained two of the three marks because they engendered power of ten errors or because they used only one point, or because their triangle was too small.

(b)(v) [HL] & (d)(v) [SL] Only a minority were able to use the data to calculate the charge transferred correctly.

(b)(vi) [HL only] Determinations of the energy used were also generally weak with some answers that were ludicrously out of range.

[HL only] Atoms

(c) [HL only] Many candidates were able to give a complete description of the photoelectric effect.

(d)(i) [HL only] Although the majority were able to relate work function to the physics of the electrons in the metal, some could only respond in terms of the minimum frequency required to produce a photocurrent. This did not generally score marks without some supporting remarks.

(d)(ii) [HL only] Generally, candidates were able to score at least two marks. Work was marred by power of ten errors and by inabilities to convert between the electrovolt and the joule. A major reason for errors was that candidates often did not begin with a clear statement of the photoelectric equation followed by substitution in an organised way.

(e) [HL only] Answers to this type of question were rather better than in previous sessions. Many were able to connect the electron as a standing wave to the integer value of the wavelength and hence the discrete values of the energies.

(f) [HL only] Significant numbers scored two out of three marks. There were some good attempts to link the wavefunction idea to the probability ideas of the theory.

9 [HL] & 6 [SL] Car engine/Motion of a car

This was another question where a single context was used to develop a number of separate areas of physics. The mechanics proved to be testing for candidates even though the problems had been posed in different contexts in previous examinations.

(a) [HL only] This simple gas law calculation was surprisingly badly done. Certainly similar questions have attracted better scores in previous examinations. Common errors included the inevitable failure to work in kelvin, and simple arithmetic errors.

(b) [HL only] Most candidates were able to describe the constant volume nature of the change in question.

(c) [HL only] Many candidates scored full credit in a question that has been well rehearsed in previous examinations. The zero change in thermal energy transfer was common and many were able to deduce that ΔU is therefore equal to $-W$. This led immediately to a deduction of temperature decrease.

(d) [HL only] Almost all recognised that the work done was related to some area under the graph. In a small minority of cases the exact specification of the area was too imprecise to gain the second mark.

(e)(i) [HL only] It was common to see a correct value for the volume of fuel used though not a correct unit.

(e)(ii) [HL only] Many were able to arrive at a travel time for the fuel and therefore the distance travelled. However, routes were indirect and lengthy and few could see a direct way to the answer.

(f) [HL] & (a) [SL] There were at least two routes to tackle this problem. Some solutions were so confused that it was difficult to decide which method had been used. Common errors included: forgetting that the initial speed was 12 ms^{-1} not zero, power of ten errors, and simple mistakes in the use of the kinematic equations, or failure to evaluate work done = force x distance correctly. However, many candidates scored partial credit. Scores of two or three out of the maximum four were common showing that many are persevering to get as far as they can.

(g)(i) [HL] & (b) (i) [SL] Many correct solutions were seen. Candidates are clearly comfortable with the use of the equation force = power/speed.

(g)(ii) [HL] & (b)(ii) [SL] The method to be used here was obvious to many. What was missing was a clear appreciation of what was happening in terms of resistive force in the system. Many scored two out of three because they indicated a sensible method but did not use the correct value for the force. Scoring two marks does require that the explanation of the method is at least competent. Those candidates who give limited explanations of their method leading to a wrong answer will generally accumulate little credit. A suggestion (never seen in answers) is that candidates should have begun from a free-body force diagram which would have revealed the relationship of all the forces.

(h)(i) [HL] & (c)(i) [SL] The major problem here was that most candidates did not recognise that 1500 N of force acting at each of four wheels will imply a total force of 6 kN. Again, partial credit was available only if it was clear what the candidate was doing and what the error was.

(h)(ii) [HL] & (c)(ii) [SL] Statements of Newton's first law were surprisingly poor. As in previous examinations, few candidates appear to have learnt this essential rule by heart and they produce a garbled and incomplete version under examination pressure. The first law was then only loosely connected to the particular context of the question. Candidates have apparently not learnt to relate the physics they learn to everyday contexts.

Recommendations and guidance for the teaching of future candidates

- Candidates should be encouraged to learn definitions so that specific details do not evade them when under examination pressure.
- Use of diverse contexts for question practice.

- Encourage candidates to read questions completely and accurately.
- Develop good presentational skills in candidates. Too many continue to lose considerable numbers of marks through careless and unclear presentation of answers.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 25	26 - 31	32 - 37	38 - 43	44 - 60

General comments

Almost the full range of marks was seen, with the vast 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 summarised below. These comments are appreciated by question setters.

Higher Level

172 of the 183 centres found the level of paper difficulty appropriate. 8 thought it too difficult. None thought it too easy. 140 centres thought the paper was of the same standard as last year. 19 centres thought it more difficult. 16 centres thought it easier than last year. Of the 182 centres responding, 159 thought that the presentation of the paper was good to excellent. 23 centres thought it was fair. None thought the presentation was poor or very poor.

Option E (Astrophysics) is by far the most popular option, followed by G (Electromagnetic waves), I (Medical Physics) and H (Relativity) with relatively few centres attempting F (Communications) or J (Particle physics).

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

General difficulties (HL and SL)

- Realising that answers will be scanned and so dark pens or dark pencils must be used
- Highlighting key phrases or data in a question
- Knowing what the symbols represent in a data book formula or equation

- Knowing that incorrect units, although not penalised in a final answer, will result in a loss of marks awarded for correct working
- Powers of 10 and unit multipliers
- Formula for the surface area of a sphere
- The inverse square law
- Careless arithmetic and algebraic errors. Calculator mistakes are common
- Showing working in full in 'show that' questions. Proof of calculation is required
- General layout of working in numerical questions - needs to be planned and methodical
- Crossing out work that is correct
- Not using a ruler in drawing diagrams
- Paying little attention to the number of marks awarded for each part question. Often candidates provide fewer key facts than required
- Paying little attention to specific command terms - outline, show that, calculate, determine, explain, estimate etc...
- Sequencing the presentation of facts to support an explanation or description
- Standard definitions – these were generally poor

Higher Level difficulties

These also apply to SL common questions.

- Knowing the unit for *d* in the stellar magnitude equation
- The values of the Chandrasekhar and OV limits for neutron stars
- Referring to the remnant mass of a star
- Characteristics of CMB radiation
- Correct use of the conventional units for Hubble's constant
- Describing the nature of FM
- Operational amplifier circuits

- Sequencing events in mobile phone communications
- Knowing the function of a Cellular Exchange (MSC)
- Standard definitions of 'near point', 'coherent' and 'monochromatic'
- Phase change on 'hard' reflections
- Relativistic kinematics, especially proper time, simultaneity, time dilation and use of the relative velocity formula
- Relativistic mechanics, especially the use of the units MeV, $MeVc^{-1}$and $MeVc^{-2}$
- Application of the equivalence principle
- Lack of reference to geodesics
- CT imaging: Sequencing the steps in the process
- Therapeutic use of radio-isotopes
- Use of the available energy equation for particle collisions
- The wire chamber - but modest improvement is evident
- Deep inelastic scattering and evidence for quarks, colour and gluons

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

The best candidates have fully covered the syllabus, show good understanding, can manipulate equations, take care with units, show all working in a methodical way and explain concepts with clarity. The weakest candidates often fail to read the whole question, have poor knowledge of concepts, lack conciseness and clarity in answers, are reckless with units, do not show all working or use the wrong equation. Clearly many candidates have studied past papers and are able to demonstrate 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, which possibly indicate that this is the type of question with which they are most familiar. Options A, B, E, and G at SL and E, G, and I at HL are very popular and most candidates make a good effort to tackle these questions.

Noted improvements at HL

These also apply to SL common questions.

- Very few candidates answering fewer or more than two Options

- Keeping responses within the answer box provided

Some improvement in knowledge or understanding was seen in the following syllabus areas:

- Using peak wavelength in a black body graph
- Use of the stellar magnitude - distance equation (but see weaknesses above)
- Interpretation of FM waveforms
- Signal sampling and analogue to digital conversion
- Calculations involving decibels
- X-ray tube design
- Length contraction
- Description of the twin paradox
- Kinematic calculations involving the Lorentz factor, gamma (but see difficulties above)
- The statement of the equivalence principle (a moderate improvement)
- Quantum numbers and their conservation rules

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

The * comments for Options E to J also apply to SL candidates. SL unique questions are covered in the SL P3 section of this report.

Option E - Astrophysics

This was easily the most popular Option, most often in combination with Option G.

*1. (a)(i) was easy, but many chose not to state that the occurrence of nuclear fusion was the obvious difference between stars and planets. In (ii) it was common for answers to state a characteristic of either a stellar cluster or a constellation but not both. (b) was well answered. In (c) nearly all candidates correctly found the star's surface temperature using the peak wavelength of the graph.

*2. (a) provided two easy marks although in (ii) some candidates stated that the distance to Cepheids was variable. In (b) candidates often struggled to determine the period of the Cepheid from the graph or to use the mean value for apparent magnitude, but usually managed to gain some marks for correct working. Far too many candidates did not know that the unit of *d* in the stellar magnitude equation was the parsec. In (c) many candidates failed to convert parsecs to metres and lost marks.

*3. In (a) far too many candidates did not refer to characteristics such as: CMB is blackbody EM radiation peaking at 2.7K, has no specific source, is isotropic *etc*. The fact that CMB was a specific prediction of the Big Bang model, long before its discovery, was generally not mentioned in (b). Many candidates gained at least one mark for stating that the wavelength or Big Bang temperature was consistent with expansion or 'cooling' of the universe.

*4. In (a) most candidates correctly referred to the mass-luminosity equation, but then asserted that luminosity was proportional to temperature without consideration of a star's surface area. (b) was answered well by most. In (c)(i) the Chandrasekhar and Oppenheimer-Volkoff limits (or their values) were both expected but not often provided. Also it was common to refer to a star's 'mass' rather than 'remnant mass' or 'mass of the core'. Many candidates realised that a pulsar was being described in (c)(ii).

5. In (a) there were far too many vague responses that just stated 'galaxies are red-shifted'. Many correct answers were seen in (b), but there were also many power of ten errors where kms^{-1} were not used in the calculation of distance. Another common mistake was to use the observed frequency in the denominator.

Option F - Communications

This option was chosen by few candidates.

*6. (a)(i) was poorly answered as most simply reworded the question and did not refer to the significance of signal wave displacement. In (ii) far more could draw the signal wave with the correct amplitude and period. Both parts of (b) were done quite well, but with the usual power of ten errors in determining signal frequency. In (c) the relative advantages or disadvantages of FM compared to AM is a common question and was well answered.

*7. (a) was an easy two marks, although there were many power of ten errors. Most understood that the quantisation error was 1V in (b) and determined that 12 levels were needed and so 4 bits. A few chose other quantisation errors for ECF marks. (c) was another easy mark, but all 4 bits (0111) were expected.

*8. (a) The meaning of the term attenuation is well known by most. In (b)(i) many were able to determine the maximum signal distance of 22km and scored three marks very easily. Most of the others scored zero. (b)(ii) was very easy, but quite a few did not realise that a velocity needed to be calculated.

*9. Infinite input impedance was the most popular answer to (a)(i). In (ii) the gain is -5, but many omitted the negative sign or used the formula for a non-inverting op-amp. However, ECF was applied for use of the previous wrong answer in (iii). Almost no correct answers for the output characteristics were seen in (b).

*10. Candidates often failed to sequence their answers in a logical way. Many still believe that what the Subject Guide calls a Cellular Exchange (more generally known as a MTSO or

MSC) is a process rather than a physical switching centre. This is clearly a topic where a diagrammatic approach is needed. http://cordsplus.com/phoneinfo/ portal/cellularsystem.html provides a reasonable summary.

Option G - Electromagnetic waves.

This option is almost as popular as Astrophysics.

*11. Definitions of focal point in (a)(i) sometimes failed to mention the principal axis. The ray diagram in (ii) was an easy three marks for almost all. In (b)(i) most vaguely knew what the 'near point' was, but very few could give a standard definition of it. Many stated that it was a distance. Very few knew that the magnifying glass magnification was a maximum for an image at the near point. (c) were very easy marks for most candidates.

*12. In (a) the terms 'coherent' and 'monochromatic' were often explained in a clumsy fashion. Formal definitions are easy to learn, but are often lacking. The phase difference, in degrees or radians, was usually stated correctly in (b), although many gave a path difference. In (c) most could re-arrange the data to obtain the answer given for wavelength, but often not very convincingly. Determining the number of lines per metre for the diffraction grating was difficult for many in (d). Quite often the wrong angle, or the wrong value for *n* was used. The final reciprocal was often missing.

13. The diagram in (a) was done well by many. However. common omissions were the vacuum and the correct accelerating polarity of the EHT supply. In (b) most candidates were able to suggest that the accelerating potential difference was too low for inner electron ejection in the target anode, but concisely worded answers were rare.

14. In (a) the correct thin film formula from the data booklet was sometimes chosen, but many candidates were able to answer the question using first principles. A common mistake was was to give the half wavelength value in air rather than oil or to forget the phase change on the hard reflection. Few could give a well reasoned answer to (b) and were often lucky to score one mark.

Option H - Relativity

*15. (a) was poorly answered. The only acceptable answer is that Judy (specifically her clock) is at both events. That is, the events take place at the same point in space for her. Many mistakenly referred to 'the events occur at rest' or 'the events occur in the same reference frame' - these are terms that have no real meaning in Relativity. (b) and (c) were generally well done by most, but not always using the most obvious units 'years' and 'light years'. Those who worked in seconds and metres were given full credit, but made hard work of the question. Unfortunately 99% of answers to (d) were, as usual, incorrect. Almost every candidate explained that the signal from P will reach Judy first - which is irrelevant. The question is about which signal was emitted first in Judy's frame. Another common mistake was to state that observer S is seen to move away from planet P by Judy. For Judy, S moves away from the signal travelling from P. (e) was answered quite well and far more candidates gained some marks by referring to the apparent symmetry and consequent, paradoxical, reduced ageing of both twins seen from the opposite frame. The actual lack of symmetry was then usually stated correctly.

16. (a)(i) In any question with units expressed in terms of MeV and c there is enormous potential for confusion. However a reasonable number are able to use the relativistic energy - momentum equation ($E^2 = (mc^2)^2 + p^2c^2$) correctly. The most common mistake was to try to make use of the value of 'c' in the calculation instead of just sticking with the values given. In (a)(ii) few could determine gamma. (iii) was much easier. (b) required use of the relativistic velocity addition formula. Quite a few performed velocity subtraction.

17. The equivalence principle was usually stated, but not always in unambiguous terms. In (b) the two situations were often confused. Candidates were less sure of the frequency in the free fall situation and usually did not recognise the box as an inertial frame. Many were able to explain why the frequency received by P was less than f_0. Most were able to refer to the sun 'bending' spacetime. Fewer referred to geodesics or the fact that they corresponded to the circular/elliptical orbit of a planet.

Option I-Medical Physics

18. The definition of sound intensity was usually correct in (a). In (b)(i) a common mistake was to use the wrong formula for the inverse square law, but since it was a 'show that' question most got close to the answer given. (ii) was an easy two marks for almost all.

19. (a) In describing the process of computed tomography (CT), a minority did well. Common problems included poor sequencing of the steps involved, not mentioning X-rays and confusion with MRI. (b) was usually correct. In (c) there were two popular methods used and many correct answers. Mistakes included using 0.65 instead of 0.35 and logarithmic errors.

20. (a) was an easy mark, but many were not specific about the values relating to a particular medium. (b)(i) was another easy mark but the calculation of muscle thickness in (ii) was error prone. Many candidates forgot to halve the time difference between the reflected pulses. ECF marking was often required. (c) was done reasonably well, but with quite a few getting the advantages and disadvantages confused.

21. In (b)(i) many candidates could determine the energy absorbed, but then did not know what to do next. The unit eV is frequently poorly understood. The time period of 5 days was often ignored. In (c)(i) many candidates stated that the isotope with the shorter half-life was preferable as it provided a smaller, safer dose. They missed the point that this is a therapeutic technique and that the source will eventually be removed. (ii) was well answered.

Option J - Particle Physics.

Very few candidates chose this option.

*22. In (a)(i) many candidates were aware that Pauli's exclusion principle applied only to fermions and that Kaons were bosons. In (ii) the production of quark/antiquark pairs with colour/anti-colour was frequently mentioned as was the impossibility of producing free quarks due to colour/quark confinement. In (b)(i) a valid reason why the Feynman diagram was for a weak interaction was usually given, but in (ii) very few candidates could convert the mass of the W particle to kg. (c) was answered well, although a few candidates stated that strangeness would not be conserved - which is irrelevant.

23. (a)(i) was often correctly answered but in (ii) many mistakes were seen in the use of the available energy equation. Correct answers were rare. In (iii) the advantage most often given was greater available energy in the synchrotron and the disadvantage most often given was the loss of energy in the form of synchrotron radiation. (b) required the operation of the wire chamber to be described. Very few candidates scored full marks. Missing points included: failing to mention a gas, failing to state that the wires were at high potential difference /charged, failing to explain what happens to the ions produced and generally not sequencing answers effectively.

24. In (a) candidates often failed to mention that the scattering involved high energy leptons. Both parts of (b) were very poorly answered, but there were a few responses that referred to momentum conservation as an argument for gluons.

25. (a) is a common question. The usual mistake was to use a single electron or work in mixed units. In (b) many candidates made a good effort to explain why the formation of particle - antiparticle pairs became impossible as the universe cooled by referring to their previous answer. They were usually able to explain the continuing annihilation of matter and antimatter. They were less certain about explaining the initial or subsequent imbalance.

Recommendations and guidance for the teaching of future candidates

The option topics allow candidates to experience some of the more challenging and interesting areas of Physics. The importance of the fundamental principles of the subject should not be underestimated. Definitions and statements of laws are sometimes poorly expressed or largely guesswork. In general, candidates tend to perform less well on the descriptive parts of questions. These are often the cause of the difference between a mediocre and good grade. In setting private study exercises it is helpful for candidates to be given not only numerical questions but also plenty of extended response questions which are marked rigorously.

A common misconception is that units do not matter - because the incorrect or missing unit in a final answer is usually not penalised. This is a dangerous assumption because mistakes with units, within the calculation, will obviously lead to an incorrect numerical value or power of 10 error. These mistakes are penalised. Rigorous treatment of units is a fundamental and essential part of any Physics course, but based on current evidence units are not well handled by a large percentage of candidates. Teachers are encouraged to set exercises involving the manipulation of units wherever possible and to ensure that units feature prominently in any worked examples provided.

Past papers provide the opportunity for essential practice with the style of questions candidates will face. Giving candidates model answers (as well as past markschemes) allows them to understand the level of response that is expected. These are often provided in IB Physics textbooks. In many centres model answers to homework exercises are also routinely provided. The marking of key phrases in a question should be encouraged as so often an instruction or piece of information is missed. The mark for a question, given in the margin of the paper, is a useful indicator of the detail required in a response.

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 and data booklet can be provided in teacher-annotated form, with textbook page references, web-site links and past paper question references. Although time consuming, it is so easy to do since both documents are in digital format. If they cannot be provided in this form at the beginning of the course, then the annotations can be added by candidates as the course progresses.

Teachers are advised to have sessions, during revision, to explain the use of every equation and all items of data in the Data Booklet. G2 comments sometimes comment that questions test information that is not in the Subject Guide. It is important to remember that the Subject Guide provides a framework – a list of aims, objectives and assessment statements - it is not meant to be a definitive list of facts. There are several excellent IB textbooks that interpret the various objectives. Physics department's schemes of work will usually make use of many additional online sources of information. IBO's OCC, Wikipedia, Hyperphysics, CERN, NASA, Physics.org, outreach.atnf.csiro.au, phys.unsw.edu.au, etc, etc.. provide a wealth of relevant and inspirational material. These can be organised by teachers into a very valuable learning resource, to supplement textbooks, in the teaching of each of the options (as well as the Core).

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 11	12 - 17	18 - 21	22 - 24	25 - 28	29 - 40

General comments

Almost the full range of marks was seen, with the vast 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 summarised below. These comments are appreciated by question setters.

Standard Level G2 feedback

136 out of 144 centres responding found the level of difficulty appropriate. 101 centres thought the paper was of the same standard as last year. 20 centres thought it more difficult. 16 thought it easier than last year. 127 centres thought that the clarity of wording was satisfactory to excellent. 1 centre thought that the presentation of the paper was poor, mainly

due to the consecutive question numbering. 127 centres thought that the presentation was satisfactory to excellent.

Options A (Sight and wave phenomena), E (Astrophysics), B (Quantum Physics) and G (Electromagnetic waves) continue to be the most popular, whilst options C (Digital technology), D (Relativity and particle physics) and F (Communications) are chosen by far fewer candidates.

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

These difficulties are unique to SL.

- Colour mixing
- Discussion of polarization by reflection
- Doppler effect application
- Algebraic manipulation of decay constant and half-life
- Determination of de Broglie wavelength
- Discussions of atomic line spectra
- CCD calculations

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

The best candidates have fully covered the syllabus, show good understanding, can manipulate equations, take care with units, show all working in a methodical way and explain concepts with clarity. The weakest candidates often fail to read the whole question, have poor knowledge of concepts, lack conciseness and clarity in answers, are reckless with units, don't show all working or use the wrong equation. Clearly many candidates have studied past papers and are able to demonstrate 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, which possibly indicate that this is the type of question with which they are most familiar. Options A,B,E, and G at SL and E, G, I and H at HL are very popular and most candidates make a good effort to tackle these questions.

Noted improvements unique to SL.

- Description of the Doppler effect
- Application of the Rayleigh criterion
- Atomic energy level calculations

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

These comments apply to SL unique questions. For common questions, see HL section.

Option A - Sight and wave phenomena

1. (a) and (b)(i) were easy marks, but many treated the colours as pigments. (b)(ii) was answered quite well with a small number of candidates referring to rods instead of cones.

2. (a) was usually answered correctly, but it is worth emphasising that it is the perceived frequency that changes. In (b)(i) there were many correct answers, but sometimes the wrong Doppler equation was used or an incorrect sign convention chosen. Having found the minimum frequency (at position B) the vast majority then stated, in (b)(ii), that frequency decreased from B to C. This is a question that needs careful discussion in class with future candidates.

3. An improvement in the answers to (a) was noted. In (b) very few omitted to use the factor of 1.22 and full marks were often scored for both calculations. In (c) most were aware that the pupil radius was smaller and that the subtended angle became larger, but then some mistakenly referred to the distance between the towers becoming larger. Overall the question was well answered. (d) was poorly answered with many being unable to make it clear that reflected light from the sea would be partially horizontally polarized. Some just referred to the darkness of the sunglasses' lens.

Option B - Quantum physics and nuclear physics

4. The de Broglie hypothesis was sometimes stated poorly and symbols sometimes not defined. In (b)(i) the kintetic energy was usually correct, but in (ii) far fewer correct answers were seen due to both algebraic and arithmetic errors. A common mistake was to treat the de Broglie wavelength as electromagnetic.

5. In (a) the logical sequence is: line spectra ➡ discrete photon energy ➡ discrete electron transitions ➡ discrete electron energy levels. However, very few were able to sequence their answers in this way. Despite this there were many reasonable answers. In (b)(i) many correct answers were seen, but there were some answers where the de Broglie formula was mistakenly used. (ii) was poorly answered as few could explain that a 12.5eV photon did not match any of the possible transition energies.

6. (a) was an easy mark. In (b) about half of the candidates could derive the relationship between half-life and decay constant, but many were completely lost. The half-life calculation in (c) was generally well done, but a common mistake was to use 0.65 as the fraction remaining.

Option C - Digital technology

7. (a) was generally well answered as was (b)(i). (b)(ii) provided very few fully correct answers with relatively few scoring marks for working. Most failed to realise that the number of electrons needed to be found. Many do not seem to start by summarising the data and equations that might be needed (for example, $E = hf$, $Q = CV$) or drawing a quick sketch to help 'visualise' the situation.

Questions from 8 onwards were also on the HL paper 3. They are marked with * in that section.

Recommendations and guidance for the teaching of future candidates

See HL section.