November 2014 subject reports

PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 15	16 – 27	28 – 40	41 – 49	50 – 60	61 – 69	70 – 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 14	15 – 26	27 – 37	38 – 47	48 – 56	57 – 65	66 – 100

Higher level and standard level internal assessment

Component grade boundaries

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

The range and suitability of the work submitted

Moderators were impressed by the scope and range of practical work. Most centres had a comprehensive practical program and teachers were assessing appropriate work. Although mechanics has traditionally been the main focus of practical work, there is a range of hands on activity in all major physics topic areas, including the relativity option (but not for IA). The quality of most candidate work was impressive, and all centres demonstrated hard work and determinism.

Candidate performance against each criterion

Design (D) The majority of centres used appropriate and well-established design prompts. The domino investigation, the ball bounce, the cantilever, the ball drop and crater, and so on, are all well represented. In a few cases, however, the prompts were not appropriate, such as asking a candidate to design an investigation to confirm Hooke's law, or where the teacher provided both the independent and dependent variables. Good design prompts are ones that have candidates looking for a function between two variables, not a specific value. Candidates need to be reminded that for a complete under design variables need to be defined (and a vague statement 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. No hypothesis is needed under design, and the better design investigations are ones where the candidate does not know the theory or relevant equation. Design is not a research or textbook based activity. A number of centres are performing two design activities and then two separate DCP and CE investigations for assessment.

Data Collection and Presentation (DCP) As expected, candidates often earn high marks under the DCP criterion. Candidates are making good use of ICT, and word processing their reports and using graphing software. This is to be encouraged. Raw data always has uncertainty, and the candidate should address this. Moderators are looking for a brief statement as to why the candidate gives a particular value of uncertainty, and this holds for both raw and processed data. When assessing DCP, candidates are expected to have produced graphs. There were some cases where graphs would have been relevant but candidates just made calculations. Examples like this cannot earn 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 (CE) This continues to be the most difficult criterion for candidates. Under CE aspect 1, candidates need to think beyond the given data in order to provide a justification based on a reasonable interpretation of the data. Such insight might look at the extremes of the data range, the origin of the graph, the y-intercept, for some physical meaning. Candidates might even give the overall relationship some physical interpretation (perhaps a hypothesis). Teachers need to look for this when awarding aspect 1 a complete, as many times moderators had to change a "complete" to a "partial". Overall, aspect 1 more often than not was not able to reach a complete. If candidates perform a standard and well-established physics lab, and CE is assessed, then it is unlikely that they can really come up with weakness or improvements. CE is best assessed when candidates have also 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, 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. It is also recommended that simulations not be used for assessment. Because the IA mark is part of the candidate's overall 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 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 as well as on graphs.

Further comments

The November 2014 moderation for physics internal assessment had very few procedural problems. Cover sheets, instructions, signatures were properly included. As in the past, there were a variety of 4/PSOW forms, but they all included the necessary information and so this variation was satisfactory. The majority of candidate reports were word processed and graphs were drawn on graphing programs. There was a good use of ICT in various investigations too, many incorporating free-software. Often teachers included written comments on the candidate script about their assessment, and this greatly helped the moderators understand the teacher's marks. There were a few centres that included only two assessed samples of work on their 4/PSOW. It is highly recommended that candidates have more than two opportunities to earn their best marks.

It is clear that the current IA expectations are understood and that teachers have aligned much of their work to allow candidates to succeed at IA. Most moderation resulted in no changes of marks, while in a few cases marks were increased and in a few more cases marks were moderated down. Teachers need to know that when their marks are moderated down it is only done with specific reasons and justification. Moderators are trying their best to support the teacher's judgment.

Higher level and standard level paper one

Higher level component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 10	11 – 13	14 – 19	20 – 22	23 – 26	27 – 29	30 – 40

Standard level component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 7	8 – 9	10 – 13	14 – 15	16 – 17	18 – 19	20 – 30

General comments

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

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

Only a small percentage of the centres taking the examination returned G2s. We can only assume that those who saw no need to complete a G2 form were, in general, happy with the papers. For SL there were 17 responses from 198 centres and for HL there were 16 responses from 268 centres. While we would like to thank those who took the trouble to provide G2 feedback, we would urge all centres to contribute; comments from teachers are carefully considered and inform the process of setting realistic and fair grade boundaries given the nature of the paper.

The replies received indicated that the papers were generally well received with many of the G2s containing favourable comments. A majority of the teachers who commented on the papers felt that they contained questions of an appropriate level, although there were a significant number of teachers who felt that both the SL and the HL were slightly more difficult than last year’s paper. With few exceptions, the teachers thought that the presentation of the papers and the clarity of the wording were either satisfactory or good.

Statistical analysis

The overall performance of candidates and the performance on individual questions are illustrated in the statistical analysis of responses. These data are given in the grids below. The numbers in the columns A–D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank.

The question key (correct option) is indicated by a shaded cell.

The *difficulty index* (perhaps better called facility index) is the percentage of candidates that gave the correct response (the key). A high index thus indicates an easy question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	425	241	524	88	10	40.68	0.58
2	117	451	319	397	4	65.84	0.51
3	114	41	108	1021	4	79.27	0.26
4	64	341	759	117	7	58.93	0.64
5	829	190	177	91	1	64.36	0.52
6	8	113	489	677	1	52.56	0.34
7	637	160	419	64	8	32.53	0.40
8	257	667	172	189	3	51.79	0.53
9	894	87	96	209	2	69.41	0.47
10	792	235	113	138	10	61.49	0.72
11	127	1036	68	56	1	80.43	0.16
12	35	68	746	435	4	33.77	0.61
13	197	789	205	93	4	61.26	0.47
14	167	896	188	36	1	69.57	0.43
15	79	891	243	73	2	69.18	0.32
16	438	222	479	144	5	37.19	0.22
17	769	180	126	203	10	59.70	0.48
18	31	1065	91	97	4	82.69	0.35
19	264	751	72	189	12	20.50	0.18
20	479	223	42	540	4	41.93	0.41
21	120	26	993	143	6	77.10	0.34
22	122	270	69	825	2	64.05	0.61
23	140	185	131	827	5	64.21	0.56
24	229	956	80	20	3	74.22	0.19
25	263	141	29	851	4	20.42	0.36
26	99	393	104	679	13	52.72	0.44
27	106	705	274	198	5	54.74	0.58
28	50	40	1050	145	3	81.52	0.34
29	234	886	104	57	7	68.79	0.49
30	187	108	872	115	6	67.70	0.55
31	876	105	82	210	15	68.01	0.58
32	417	212	439	215	5	16.46	0.24
33	75	479	64	664	6	51.55	0.57
34	644	508	88	41	7	50.00	0.63
35	386	530	144	212	16	29.97	0.31
36	40	999	161	78	10	77.56	0.38
37	893	288	46	48	13	69.33	0.27
38	167	580	152	358	31	45.03	0.48
39	78	53	1106	42	9	85.87	0.31
40	247	850	123	53	15	65.99	0.61

Number of candidates: 1288

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	694	276	40	75	1	63.90	0.30
2	65	148	467	401	5	43.00	0.43
3	127	271	362	325	1	54.88	0.39
4	160	55	183	685	3	63.08	0.43
5	497	272	205	109	3	45.76	0.41
6	119	169	214	583	1	53.68	0.48
7	360	166	497	61	2	45.76	0.35
8	628	130	18	308	2	57.83	0.28
9	20	189	401	472	4	43.46	0.39
10	511	274	227	69	5	20.90	0.26
11	114	204	141	625	2	57.55	0.29
12	76	726	51	231	2	66.85	0.33
13	61	131	738	153	3	14.09	0.28
14	131	792	62	98	3	72.93	0.29
15	549	258	106	166	7	9.76	0.00
16	85	238	607	151	5	55.89	0.60
17	51	595	138	301	1	54.79	0.10
18	59	747	126	148	6	68.78	0.41
19	797	76	178	33	2	73.39	0.39
20	135	241	142	560	8	51.57	0.46
21	130	366	228	357	5	32.87	0.41
22	142	728	134	76	6	67.03	0.37
23	86	88	696	210	6	64.09	0.49
24	44	911	90	39	2	83.89	0.30
25	294	486	133	158	15	27.07	0.11
26	330	141	487	118	10	44.84	0.48
27	278	272	116	414	6	38.12	0.52
28	628	325	59	67	7	57.83	0.32
29	408	281	288	99	10	26.52	0.23
30	226	360	246	234	20	33.15	0.44

Number of candidates: 1086

Comments on the analysis

Difficulty

The difficulty index varies from about 16% in HL and 10% in SL (relatively “difficult” questions) to about 86% in HL and 84% in SL (relatively “easy” questions). About 80% of the questions fell within the 30–80 range giving the papers 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 “distracters” 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 G2s.

SL and HL common questions

SL Q3 and HL Q2

Air resistance depends upon speed, so initially, when the body is increasing in speed, the acceleration will be decreasing. Hence A and C can be immediately discounted. Many candidates chose C which indicated that they clearly had not read the question carefully. As the body approaches terminal velocity so its acceleration approaches zero, indicating D as the correct answer. Unfortunately though, D also indicates a sudden decrease in the acceleration initially whereas it should be a gradual decrease (as in C). Both B and D were accepted as correct answers to this question.

SL Q10 and HL Q7

This question was poorly done but it did discriminate effectively. A quick glance at the possible responses shows that they all have different units – hence this should be the preferred method of solution (in such cases it is a waste of time to work out the answer fully). Thermal capacity is in JK^{-1}. *Pt* gives Joules, hence the correct response can only be C.

SL Q13 and HL Q12

The most popular response was the incorrect C. It would seem that these candidates did not appreciate that the intensity of a wave is proportional to the *square* of the amplitude.

SL Q23 and HL Q28

A few comments from the G2 forms suggested that B was indeed possible with n = 3 and m = 5. This is, however, only a mathematical possibility and there is no evidence that candidates were distracted. Over 80% of the HL candidates and 60% of the SL candidates selected the correct response, recognising the reaction as fusion.

SL Q25 and HL Q35

There were a few comments that this was not on the syllabus. Assessment statement 8.1.1, however, clearly requires the candidates differentiate between a “single process” and a “cyclical process” when converting thermal energy into work. This question was a very direct assessment of the syllabus item and their poor performance may indicate that the topic had not been well taught.

SL Q30 and HL Q38

The relevant assessment statement is 8.6.6. A simple sketch (of, for example, a measuring cylinder full of water which reduces an exaggerated 50% when the temperature drops) should immediately lead to the correct answer.

SL Q29 and HL Q1

This was, perhaps, a slightly difficult question to have as the first question in the HL paper, but candidates must be taught throughout their course to consider the units of every concept they encounter. Indeed the concept is often encapsulated in the units. “Surface heat capacity” can only be in $Jm^{-2}K^{-1}$ and since $J = kgm^2s^{-2}$, C must be the correct response.

HL Questions

Q16

A was a popular choice, indicating that some candidates were unsure of the relationship between the number of photons per second in a light wave, the intensity of the wave and its frequency.

Q19

This should have been a straightforward question but many candidates opted for B. This highlights the importance of carefully reading the question. Candidates must not assume that all relevant information will be on the diagram.

Q25

The majority of candidates favoured D. A simple sketch will show that at a height of 3*r* above a planet, the distance to the centre of the planet is 4*r*.

Q26

The only reasonable distractor was B, with some candidates clearly not taking into account that it was a *negative* ion.

Q32

The most popular responses were A and C, both of which are incorrect. One can only assume that the candidates did not read the question with sufficient care and, on seeing the words "metal" and "electrons", automatically assumed the photoelectric effect was involved.

Q34

A simple diagram showing the depletion of the sample with increasing half-lives is needed. Those who chose B were perhaps jumping to conclusions without such a visual image.

SL Questions

Q2

It was surprising to see the number of candidates who clearly did not realise that the square root involves halving the percentage uncertainty.

Q7

A was a popular choice. Candidates should be taught the conceptual difference between momentum and kinetic energy and realise that if the momentum of two moving objects of different mass is the same, then their kinetic energy can never be the same.

Q8

Newton's third law is often poorly understood, so it is pleasing to see so many correct responses to this question. If candidates have been correctly taught that the force of X on Y will be equal and opposite to the force of Y on X, then the *only* possible answers are A or B.

Q15

The candidates found this question to be the most difficult of the paper, with the correct answer being the *least* often selected! The key to spotting the correct solution is a simple diagram showing that after the particle has travelled a distance of $x_0/3$ then its distance to the equilibrium position is $2x_0/3$. Substituting this value into the relevant equation in the Data Booklet gives response C directly.

Q21

The statistics suggest that many candidates were confused by this question. Field lines have to start and finish on a charge which means that only A and B could be correct if only two point charges are present. But the field lines will be in the same direction on leaving a charge, hence D is the only sensible solution.

Q26

Candidates are supposed to commit certain facts to memory. So they should be able to identify U-235 as the active isotope in nuclear fuel and understand that enriching uranium involves increasing the ratio of U-235 that it contains.

Q27

As both plutonium and uranium nuclei are approximately the same size it should be clear that neither fusion nor fission can be involved in the formation of one from the other. Response C will not result in any change (as an electron *is* a beta particle) so D must be correct.

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 prompts 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:

- Read the question carefully. For example, *V* in SL Q16 refers to *volume* and not *voltage*. And the vertical axis in SL Q3 (HL Q2) refers to *acceleration*.
- Eliminate the clearly wrong responses. For example, SL Q27.
- 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. This is very clear in SL Q10 (HL Q7), but can also be used in SL Q16, 17, 19 and HL Q21.
- If two responses are logically equivalent then they must both be wrong.
- Exaggerate a variable – this will often point the candidate in the correct direction, especially if a variable is in the denominator in one response and the numerator in another.
- Draw the situation while reading the stem. A simple sketch will aid in understanding the stem and often lead the candidate to the correct response. This is particularly important for those candidates with weak language skills.
- Distinguish between cos and sin functions – mentally making the angle 90° will show which is correct.
- Use proportion: new quantity = old quantity × a fraction, where the fraction depends

upon the variables that have changed. For example, HL Q5, 10, 12, etc.
- Notice the axes on graphs and use units to attach meaning to the gradient and the area. For example, HL Q4.
- 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 search through the Data Booklet and 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 – 42	43 – 52	53 – 62	63 – 95

General comments

Most candidates made a serious effort to attempt the required number of questions and appeared to have ample time to complete the paper. Clearly many centres provide plenty of past papers, as question types which had occurred previously were well answered.

There were frequent occasions when poor handwriting made marking difficult. In particular powers of ten and decimal points were not always clear. Very frequently, examiners had difficulty in deciphering the candidate's reasoning within a calculation – and frequently this reasoning was completely absent. (See section on recommendations at the end of this report).

Only 26 centres provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage. 85% of centres thought the paper was of appropriate difficulty, the remaining centres thought it was too difficult. 58% of centres thought the paper was of similar difficulty to last year; 31% thought it more difficult and only 4% thought it was a little easier. No centres thought that the clarity of the wording or the presentation of the paper was poor; most describing these as very good or excellent.

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

- Reading the question carefully and highlighting key data.
- Layout of working from left to right then top to bottom.
- Sequencing information in descriptive questions. Flow diagrams or bullet points are rarely seen.
- Excessive use of extension sheets.
- Giving standard definitions correctly, eg work, emf.
- Handling units and powers of ten (POT) correctly in calculations.

- Careful inspection of the units and POT on the axes of a graph.
- Calculator usage, particularly radian and degree settings.
- Showing all working, a clear line of reasoning and sufficient significant figures in "show that" questions.
- Drawing a tangent at the correct point (SL) and of sufficient length.
- Choosing widely separated points when determining a gradient.
- Referring to forms of energy in questions about energy transfer.
- Solving "thermal energy transfer" questions involving specific and latent heats.
- The units eV, MeV, etc.
- The difference between a moderator and control rods (HL only)

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

- Drawing a smooth curve as a line of best-fit.
- The photoelectric effect, especially the use of the kinetic energy vs. frequency graph.
- HL: Gravitational potential and kinetic energies, escape velocity, etc. Although the idea of an increasing negative value of PE being a decrease was largely missing.
- Basic circuit calculations; although internal resistance calculations were often poor.
- Simple harmonic motion.
- HL: The Rayleigh criterion.
- Energy resources.

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

There were many common questions between SL P2 and HL P2. These are marked with * in the following section. For SL comments to unique questions please refer to the SL P2 section.

Section A

***1. [HL and SL] Data analysis question**

In general this question was accessible to virtually all candidates.

*(a) The vast majority of candidates were able to correctly draw a smooth curve that passed through (or very close to) all the data points. There were very few straight lines drawn this session.

*(b)(i) Tangents were usually drawn at the correct point, but sometimes of inadequate length. To gain the first mark the value of ΔR was required to be > 3.5Ω. A common mistake was to overlook the false origin on the *T* axis. The negative sign for the gradient was often omitted. Far too many candidates used the coordinates of a single point in an effort to determine the gradient.

*(b)(ii) Almost all candidates were able to provide the correct unit for gradient.

*(c) Error bars for R were usually correct or within the allowed tolerance.

*(d)(i) Far too many candidates used 0.78A instead of 0.78mA in determining power. In fact, powers of ten (POT) were generally poorly handled throughout the paper.

*(d)(ii) Arithmetic errors were common, but the majority of candidates could obtain a total uncertainty of 7.6%, but often failed to round this to 1sf.

2. Melting Ice

*(a) An easy question, but in finding the energy input the time of 45s was overlooked by some candidates. The specific heat capacity of ice was usually correctly calculated.

*(b) Many candidates were unable to organise their work in a linear way within the answer box. Candidates need to be taught to work from left to right across the page and use the full width of the page. Far too many candidates work from top to bottom, then move across the page to work from top to bottom again. The ruled dotted lines within an answer box are often ignored. This is a very poor technique and difficult to mark. Many candidates placed the energy required to melt the ice on the wrong side of the energy equation, however the correct temperature was often obtained.

3. Nuclear reactions

(a)(i) X is a neutron and almost all answers were correct. G2 comments suggested that the term “State the nature of X” was rather vague. This is a helpful comment, but on this occasion candidates did not seem to be affected by it.

(a)(i) Instantaneous energy release: Binding energy, (particle) kinetic energy, gamma radiation were all accepted. Heat energy was not accepted.

*(b)(i) Quite a few candidates found the mass defect rather than the mass of U-235 fissioned. The mass of a Uranium atom was often incorrect – candidates were expected to determine it from the mass number. A few stated the mass as 235g. Another common error was to find mass per second, rather than per day. However many correct answers were seen.

*(b)(ii) Working was often unclear. The power station efficiency of 0.32 was often overlooked. Whilst many candidates were eventually able to determine the power output of the power

station in W, there were also answers giving the energy output per day. Quite a few candidates used eV/s and this was accepted for 1 mark.

*(c) There was some confusion between a moderator and control rods. However, most candidates knew that the graphite moderator slowed neutrons (due to inelastic collisions) to thermal energies to maximise the probability of further fission.

(d) Outlining the energy transfers occurring in a nuclear power plant is a frequent question, but answers were often poorly organised. A simple flow diagram would suffice. Thermal energy of core > thermal energy of coolant > KE of steam > KE of turbine > Electrical energy from generator, or similar. Far too many candidates barely mentioned energy; "…heat up water to make steam which turns a turbine…" gained no marks.

4. Satellite orbits

(a) Candidates were asked to show that the shuttle could not escape the Earth's field. There are many ways of approaching this, but in general answers were good, with only the weakest candidates failing to know where to start.

(b)(i) The determination of total energy of a mass in Earth orbit is a standard classroom derivation. Most were able to reproduce it, but not everyone explained how the formula for orbital KE was derived.

(b)(ii) Determining the radius of the orbit proved difficult for most candidates with many obtaining negative values or orbits with a radius less than the radius of the Earth. This was due to carelessness with the symbols used for the two different radii.

(c) Few candidates equated a decrease in total energy with an increasingly negative value. The consequent fact that the radius of the orbit decreases and velocity increases was counter-intuitive for most candidates. Most incorrectly opted for a decrease in KE due to resistive forces.

5. CCD

(a) The energy of a single photon was often correctly determined, but there were many errors seen subsequently. Powers of ten were often incorrect, as was the manipulation of power per unit area, but many were able to determine the number of photons per second. The question gave the approximate answer, so to prove that a calculation had been done an answer to at least 2sf was expected.

(b) In determining the potential difference across the pixel the quantum efficiency was sometimes overlooked or the incorrect POT value of capacitance used. Quite a few candidates divided energy, rather than charge, by capacitance.

Section B

6. Part 1 Energy resources

*(a) In differentiating between renewable and non-renewable energy sources candidates were expected to make some reference to rate of usage compared to rate of production. Many merely stated that renewable energy sources will last indefinitely or cannot be easily depleted, which was fine for just 1 mark. Invalid responses included stating that renewable energy sources could be used over and over again, or were non-polluting, or that only non-renewable energy became “degraded”.

*(b) In describing solar panels and photovoltaic cells most candidates could describe the energy transformations for 1 mark. Few realised that some comment about how the devices operate was also required.

*(c)(i) This was an easy calculation of the efficiency of a photovoltaic cell and was well answered.

*(c)(ii) Candidates usually had no problem giving two reasons why the intensity of solar radiation was not constant. A few candidates referred to latitude which shows that they did not read the question carefully. This is a question that is frequently asked.

*(d)(i) Finding the area of the solar panel was slightly more difficult than the previous calculation, but many correct answers were seen.

*(d)(ii) The strongest candidates made use of their data to make a quantitative comparison between the efficiency of the two devices. However, there were many answers that merely stated that solar panels were more efficient.

*(e) Even if candidates did not know the specific details of the Kyoto protocol they could guess what was recommended. Reducing greenhouse gas emissions, reducing dependency on fossil fuels, greater use of named renewable energy sources, improving public transport, etc.

6. Part 2 Transformers

(f) Many candidates described the purpose of a step-down transformer. The question asked for features, such as an iron core or more primary than secondary turns.

(g) Further features such as a laminated core or low resistance coils were not often given, with explanations, as ways of increasing the efficiency of a transformer.

(h) (i) A very easy mark, 4.1W.

(h)(ii) To determine the primary current the efficiency needed to be applied correctly to the power in the two circuits. There were many correct answers, with a minority placing the efficiency on the wrong side of the equation.

(h)(iii) TV power consumption in standby mode was an easy calculation for 1 mark.

7. Motion of a ship

*(a) In describing the meaning of "work" a variety of responses were seen. The most common was "force times distance/displacement in the direction of the force". However, many candidates omitted to mention direction. $F s \cos\theta$ was accepted, but each symbol needed to be explained.

*(b)(i) The use of $F s \cos\theta$ was usually correct, but there were many POT errors with either the force or distance units.

*(b)(ii) Most candidates could find the power provided by the kite, although some used 250kN rather than its component. Expressing this power as a fraction of total power was also well done. As the approximate answer of 40% was given, at least 2sf (eg 38%) was required to obtain the final mark.

*(c) This was another "show that" question where full working and 2sf in the final answer were required. $P = kv^3$ was often derived and used to obtain an answer quickly, but there were alternative methods used. Many candidates incorrectly assumed that the work done by the engine per km remained the same.

*(d)(i) Most candidates simply used distance = average velocity × time. Others found deceleration first. This was an easy 2 marks.

*(d)(ii) Almost everyone obtained 2 marks by drawing a line of decreasing negative gradient.

(e) The Rayleigh criterion for a circular aperture was almost always used to find resolving power correctly. The third mark for finding distance was often lost as some candidates used $\tan\theta$ (with their calculator in degree mode) or used 750m instead of 1500m in their calculation.

(f)(i) Two marks were obtained for stating that the reflected light from the sea was partially plane/horizontally polarised. Most candidates obtained only one mark. Many obtained no mark as they simply stated that the light would be polarised – which is essentially rewording the question.

(f)(ii) This is a frequently asked question. Some candidates forgot to find the complement to the Brewster angle.

(f)(iii) This was a 3 mark question, so candidates needed to give a detailed response, including the respective planes of polarisation of reflected light and the polaroid, in explaining the action of polarising sunglasses.

8. Part 1 Internal resistance

*(a) Various definitions of emf were accepted, but "per unit charge" was often missed in candidate responses.

(b) This was a 3 mark question about internal resistance, so reasonable detail was expected. Candidates needed to refer to electrons/charge dissipating energy in moving through a cell and the effect on terminal potential difference.

*(c)(i) The simplest of circuit diagrams was almost always correctly drawn.

*(c)(ii) This was a “show that” question. The mark was not awarded unless the correct power of ten was shown in the calculation of emf.

*(c)(iii) Correct calculations of internal resistance were fairly rare as mistakes often occurred in using the standard equation $V = E - Ir$.

*(c)(iv) This was an easy 2 marks for determining the power output of the resistor.

(d)(i) Very few correct answers were seen. The equation of the line required is $V = E - Ir$. Hence a line of negative gradient (–1.9Ω) was required with a y intercept of 1.24V.

(d)(ii) If a candidate drew any kind of line, ECF was used when the coordinate of the intersection of the two lines was used to determine a current.

8. Part 2 Expansion of a gas

(e) Most candidates were able to identify B as the adiabatic – either by referring to the gradients or lower pressures and temperatures compared to A, or by showing PV was constant for A but not B.

(f) In determining the work done during expansion the commonest mistake was to overlook the false origin. Another common mistake was to calculate the wrong value for the energy of each square. A wide range of numerical answers were allowed by the MS.

(g) This was a 4 mark question and so candidates needed to give a detailed response. Many stated the 1st law, identified the three symbols and explained the change in each during an adiabatic expansion. Others were far less systematic. Most eventually predicted that temperature would decrease, but lost marks in their explanation.

9. Part 1 Oscillation of a mass / SHM

*(a)(i) The majority of candidates ignored the fact that there are 2 springs and so used half the correct force value. ECF was applied for a loss of 1 mark.

*(a)(ii) The conditions required for SHM were usually correctly stated.

*(a)(iii) A minority of candidates could determine ω and hence T. ECF from (a)(i) was frequently applied for full marks.

*(b)(i) The use of $\omega = 2\pi f$ was usually correct, but the subsequent determination of maximum energy was a little more difficult and mistakes in the calculation were common.

*(b)(ii) PE and KE vs. time graphs. There was some confusion with the graphs for energy vs. displacement. Most candidates drew graphs in which the KE and PE were in anti-phase and of the same amplitude, but not always with acceptable shapes. The energy axis was sometimes correctly labelled with the total energy from (b)(i).

*(c)(i) An easy mark.

*(c)(ii) This was often well answered. Most candidates mentioned that resonance occurs when the IR frequency is the same as the lattice's natural frequency.

9. Part 2 The photoelectric effect

(d) A number of candidates effectively repeated the question by stating that light had to exceed a threshold frequency to cause photoemission. To gain both marks they were expected to refer to the need for photon energy (hf) to be greater than the work function energy for the metal surface.

(e)(i) To determine the threshold frequency most candidates correctly extended the graph to find the intercept on the *f* axis. Quite large numbers of candidates misread the scale.

(e)(ii) Various methods were used to determine h. Commonly the gradient was measured, but as always candidates seemed to be unaware that they should choose points on their line as far apart as possible. The gradient in eVs was usually correctly converted to Js.

(e)(iii) The work function was also determined in a number of different ways. The easiest method was to use the *y* intercept. Most candidates did well on this question.

(f) Almost all candidates correctly drew a line parallel and to the left of the original line.

Recommendations and guidance for the teaching of future candidates

There is evidence that many candidates are becoming lax with the use of units. A common misconception seems to be that units do not matter – perhaps 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, can obviously lead to an incorrect numerical value or power of ten error. These mistakes **are** penalised. Power of ten (POT) errors are seen in the majority of scripts. Questions will often provide data expressed in terms of a derived or base SI unit together with a unit multiplier/prefix. For example, 7.8mA, 9.4MJ, 550nm. Far too frequently the unit prefix is overlooked or misinterpreted when substituting the data into a formula or equation. There will therefore be an immediate loss of mark, labelled as a POT error, with the possibility of ECF (error carried forward) being applied to any subsequent, legible working. Rigorous treatment of units and POT is a fundamental and essential part of any Physics course, but based on current evidence neither are well handled by a large percentage of candidates. Teachers are encouraged to set exercises involving the manipulation of units and POT wherever possible and to ensure that both feature prominently in any worked examples provided.

Whilst an encouraging number of candidates produced neat and concise working, presentation of calculations was, in general, poor. On occasions it was not clear where the final answer was; algebra and arithmetic often being strewn across the page with no documented purpose. The line of reasoning leading to the answer was often not communicated effectively. Teachers are reminded that good physics demands that reasoned answers are given in calculations, and whereas full credit may be gained for a bald correct answer (depending upon the particular construction of the markscheme), no part-credit or ECFs can be awarded unless it is clear what the numbers refer to. Teachers need to remind their candidates to “show their reasoning” (rather than “show their working”).

In spite of the comments above, many candidates perform better on calculation questions than on descriptive questions. Centres need to give candidates plenty of practice with both types of question and try to encourage a systematic approach to presentation by marking answers rigorously.

Candidates should be reminded that whenever an answer is continued on an attachment sheet that a **reference** to this is given in the original answer box. Furthermore, the question and part number relating to the answer on the attachment sheet needs to be specified.

Past papers provide the opportunity for essential practice with the style of questions candidates will face. Giving candidates model answers 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. Please bear in mind that the IB mark schemes, although useful sources of information for teachers and candidates, are instructions to examiners and not intended to be “model answers”.

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.

Centre G2 comments sometimes complain 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. IB's OCC, Wikipedia, wikibooks.org/wiki/IB_Physics, Hyperphysics, www.Physics.org, www.thinkib.net/physics, iop.org, www.animations.physics.unsw.edu.au/, CERN, NASA, 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 most sections of the course.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 6	7 – 12	13 – 17	18 – 22	23 – 27	28 – 32	33 – 50

General comments

Most candidates made a serious effort to attempt the required number of questions and appeared to have ample time to complete the paper. Clearly many centres provide plenty of past papers, as question types which had occurred previously were well answered.

There were frequent occasions when poor handwriting made marking difficult. In particular powers of ten and decimal points were not always clear. Very frequently examiners had difficulty in deciphering the candidate's reasoning within a calculation – and frequently this reasoning was completely absent. (See section on recommendations at the end of the HL P2 report).

Only 23 centres provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage. 74% of centres thought the paper was of appropriate difficulty, the remaining centres thought it was too difficult. 52% of centres thought the paper was of similar difficulty to last year; 35% thought it more difficult; 9% thought it easier. In fact the mean score was 2 marks more than in N13. 9% of centres thought that the clarity of the wording of the paper was poor; most describing this as good to excellent. 9% of centres described the presentation of the paper as fair; 91% described this as good to excellent.

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

Please refer to the HL P2 section.

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

Please refer to the HL P2 section.

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

Unless otherwise stated, comments in the HL P2 report apply equally to the SL P2 common questions. The comments below apply to the unique SL P2 questions or to questions where SL candidates performance was significantly different to those at HL.

1. [HL and SL] Data analysis question

(b)(i) Very poorly executed. Few SL candidates knew how to draw an acceptable tangent.

2. EMF and internal resistance

(a) Very few precise answers. Most candidates almost knew what it was but were unable to define it with the necessary precision.

3. Radioactive decay

(a) A variety of good answers.

(b) Many seemed unaware of the antineutrino.

(c)(i) Many candidates were able to determine the answer from the activity graph, but quite a few misunderstood what the question was asking for.

(c)(ii) This was done quite well, with most graphs starting at 50Bq and having the required half-life. However, too many candidates did not draw an acceptable exponentially shaped graph.

4. Part 1 Motion of a ship

(b)(ii) This is a "show that" question which means that the candidate is obliged to show their line of reasoning. Very few SL candidates did this.

(c) This was easy using proportionality, but most candidates at SL attempted to calculate k unnecessarily. Even so there were many correct answers.

4. Part 2 Melting ice

(e) A minority of candidates knew that molecules made a transition from being localised to being free to migrate, but had difficulty expressing their answers coherently. Candidates are so used to commenting on the energy transformations when ice melts, that many completely misread the question.

(f)(i) & (ii) Many good answers, although those that did not get the correct answers presented their working in such a way that part marks (ECF) were not able to be given.

(g) The significance of the temperature of the surroundings was ignored by nearly all candidates, but most were able to obtain 2 marks for suggesting that thermal energy would be lost to the surroundings causing a lower final temperature.

5. Part 1 Oscillation of a mass

(a)(i) This is a slightly different situation. Most candidates at SL did not use F and m to find acceleration. Very few added the force due to each spring and ECF was frequently applied.

(b)(ii) Care was needed in showing the constant and equal amplitudes. Many poor answers were seen.

5. Part 2 Nuclear Fission

(e)(i) Mostly good answers although it was rare to find a candidate who stated that the probability of further fusion is increased with thermal neutrons.

(e)(ii) Too many answers lacked precision referring only to the use of control rods in avoiding an explosion or meltdown.

6. Part 1 Energy resources

(b) The question was often not read carefully. Very few candidates referred to the operation of the devices.

6. Part 2 Electric Fields

(f) It was disappointing to see some candidates sketching very imprecise lines. Most fields were radial, but often with incorrect direction.

(g)(i) Another "show that" question which often elicited a jumble of numbers. Line of reasoning needs to be clear. Although there were many arithmetic/POT mistakes the field strength was often given correctly.

(g)(ii) It was extremely rare to find a zero line for the field inside of the sphere. The inverse square drop-off was often very approximate and did not always start from the surface of the sphere. The line should not touch the *x*-axis, but often did.

(h)(i) This was done correctly by a minority of candidates with many arithmetic and POT errors.

(h)(ii) Some candidates clearly do not fully understand the difference between velocity and acceleration. It was rare to find that direction of motion was given with precision. Some candidates said that the electron would stop as the field strength approached zero.

Recommendations and guidance for the teaching of future candidates

Please refer to the HL P2 recommendations.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 7	8 – 14	15 – 21	22 – 26	27 – 32	33 – 37	38 – 60

General comments

Candidates prepared well for the paper and proved that they had enough time to complete the paper. The difficulty of the options was comparable. There were many good examples of understanding in each of the questions. Almost all candidates answered all questions from two options selected; it seems that only very few candidates forgot to answer a part of a question from the selected options. Well prepared candidates answered two options, only some weaker candidates tried to answer questions from three options. The vast majority of candidates kept responses in the answer boxes provided and when extension sheets were used they were referenced within the answer box. Handwriting seemed to be at a higher level than in previous sessions and generally the answers were legible.

Only 26 centres provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage. 96% of centres thought the paper was of appropriate difficulty, the remaining centres thought it was too difficult. 65% of centres thought the paper was of similar difficulty to last year; 15% thought it more difficult and 12% thought it was a little easier. 4% of centres thought the clarity of the wording was very poor, the remaining centres thought it was very good or excellent. No centres thought that the presentation of the paper was poor; most describing this as very good or excellent.

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

Each of the questions was accessible to well prepared candidates. However, many candidates failed in explaining concepts in clarity and writing definitions of physical quantities. Generally, candidates responded well to command terms such as define, show that, compare, distinguish, etc, compared to previous sessions.

Other difficulties:

- Arithmetic and algebraic mistakes, calculator mistakes
- Power of ten (POT) errors in calculations
- Layout of working in numerical questions; it is sometimes hard to see where the mistakes occurred in a poorly laid out answer
- Sequencing the presentation of facts to support an explanation and description
- Often, there was superficial reading of questions by candidates
- Parallax method (E3.2)

Explaining Olbers' paradox (E4.2)

Evolution path of red supergiant (E5.5 and E5.7)

Sampling, applying digital conversion (F2.1)

Population inversion (G1.9)

Principal axis – definition (G2.1)

Film badge (I3.2)

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

The best candidates have clearly seen the syllabus and showed good understanding. These candidates can analyse the situations, present working in logical manner, and use proper terminology, physical quantities and units. The majority of candidates showed the ability to read and understand questions. They demonstrated understanding of facts and concepts and were able to use them with proper terminology. Most candidates proved the ability to clearly present well known facts in words and sentences. There was evidence, in numerical answers, of an improvement in the use of units and significant figures in comparison to previous sessions.

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

Option E – Astrophysics

This was one of the most popular options.

1. Night sky Most candidates showed the ability to clearly present well known facts in words and sentences.

2. Stellar radiation and parallax method The vast majority of candidates realised that one star must be further and were able to use quantities related to stellar radiation. Better candidates were able to use the relationships between the quantities (formulas). The ability to clearly describe parallax method is still not developed enough in general, but there was evidence of very clear, well-structured responses.

3. Olbers' Paradox and the Big Bang model As for previous sessions, explaining such theories and providing suggestions based on such models is accessible only for better candidates. This question discriminated well.

4. Oppenheimer–Volkoff limit This question was not easy. The majority of candidates calculated the luminosity of the star and used the balance between radiation pressure and gravitational pressure. Stronger candidates identified the evolution of the star on the HR diagram and showed the ability to distinguish between a black hole and neutron star.

5. Age of the Universe The majority of candidates answered both questions well.

Option F – Communications

This option was not so popular, and only a few good candidates showed sound knowledge of this option.

6. Amplitude modulation Generally, better candidates answered this question well. The waveform of amplitude modulated signal was well sketched only by some candidates.

7. Sampling Only well prepared candidates were able to read the graph and apply the binary conversion given. Only a few were able to suggest improvements to the system.

8. Optic fibres This question was relatively well answered, with the exception of the explanation of modal dispersion.

9. Satellite communication Better candidates showed good understanding.

10. Operational amplifier As for previous sessions, solving problems with comparators proved challenging. Only the best candidates were able to read electrical circuit symbols (published in the Data Booklet), solve electric circuits (or at least potential divider) and also had a sound knowledge of operational amplifiers.

Option G – Electromagnetic waves

This was a relatively popular option.

11. Convex lens Candidates proved that the definitions of well known conceptions could be problematic. (a)(i) was rarely well answered. Other parts of this question were answered relatively well.

12. Lasers The most common issue for this question was the mechanism for the production of laser light and population inversion. Almost all candidates were able to clearly outline the term monochromatic light and mention the use of lasers. Only the better candidates gave a brief description.

13. Sound wave interference This question discriminated well. Candidates who read and answered the questions in a superficial manner did not explain the intensity pattern in (a) and did not realise the speed change in (c).

14. X-ray diffraction This question discriminated well.

15. Oil on water surface A large number of candidates did not explain two reflected rays, and that interference was dependent on the thickness of the oil film.

Option H – Relativity

This was a very popular option.

16. Simultaneity In (a) many candidates did not present the idea of constant speed of light. In (b), candidates who did not realise that the beams returning to Daniela occur at one point in space, were usually not able to answer this part question.

17. Light clock (a) and (b)(ii) were answered well by the majority of candidates, but in (b)(i) many candidates did not explain their reasoning and/or present working not connected to the light clock used in the question.

18. Muon decay Many well prepared candidates presented good, well structured and clear answers. Some candidates struggled with (b)(ii).

19. Electron–proton annihilation Well prepared candidates showed a good ability to apply relativistic velocity addition. (b) discriminated well.

20. Gravitational time dilatation The stronger candidates clearly explained gravitational red-shift in a black hole gravitational field. In (b), some candidates applied formulae from the Data Booklet; the best candidates also explained the formula.

Option I – Medical physics

This was quite a popular option and often well scored.

21. Ear and hearing In (a), the vast majority of candidates identified the oval window on the picture and clearly explained sound energy to cochlear fluid. However, some forgot to mention pressure increase via reduction of surface area. Part (b) discriminated well, many candidates proved ability to use logarithmic response of the ear to intensity in (i). and only the best candidates were able to apply it also in (ii).

22. X-rays in medical imaging In (a) the definition of physical quantities was better than in previous years. In (b)(i), the majority of candidates calculated the ratio of blood/muscle intensities. In (b)(ii) some candidates did not read the question and answered in terms of blood instead of bone, but better candidates realised that muscle/bone resolution for X-rays is properly and widely used in medical imaging. In (c) the better candidates applied knowledge in a quite complex situation. In (d), the better candidates wrote clear answers. Only some candidates described the mechanism of enhancement instead of the role of it.

23. Treatment of bone cancers This question discriminated well between the average and well prepared candidates. Surprisingly, too many candidates were not able to describe the function of the film badge and to calculate the effective half-life of radioactive isotope in a patient. The definition of the quality factor was well presented by the majority of prepared candidates.

Option J – Particle physics

This was not a very popular option this session, but was well answered by many candidates who selected this option.

24. π^+ mesons Many candidates showed a deep understanding of fundamental interactions, conservation of baryon number and the ability to apply formula for the range for interactions of π^+ mesons.

25. Synchrotron Candidates presented their knowledge well in energy necessary for production of particles in (a). In (b) the better candidates clearly used their knowledge of electric and magnetic field. In (b)(iii) the better candidates were able to describe the need for a large radius in the terms of synchrotron radiation.

26. Electrons scattered by nuclei Surprisingly, parts (b)(ii) and (c) were not well answered. (b) (i) was solved by the majority of candidates using classical and not relativistic mechanics.

27. Early universe This question was generally answered well.

Recommendations and guidance for the teaching of future candidates

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

It is recommended that candidates:

- are informed about aims, objectives and syllabus details at early stage of study.
- at the final stages of study, check their understanding of basic terms and definitions listed in the subject guide.
- are informed about the command terms and other terms that are often used in communication between teacher and candidate during the whole of the learning/teaching process.
- study both options before or alongside the revision of core physics, so that connections amongst topics can be made.
- use the Data Booklet when solving multistep, complex problems.
- make use of past papers.
- try not only to understand and apply, but also remember precise formulations of definitions, especially of physical quantities used only in the options.
- try to connect knowledge of the options to core physics, such as the general physics quantities of energy, power, force, pressure, etc.
- study options with their teacher and class, and not independently.
- are trained to express their ideas in written form, in a logical manner and layout, showing each step of their ideas or workings. Sometimes candidates do not write obvious information such as that mass has gravity, or the speed of light is constant for each observer, this information is not implicit in their answers. If such information is necessary, especially in “show that” questions, it should be mentioned.
- are encouraged to write some words explaining their workings, even in calculations, derivations and other use of formulae. This is especially the case where answers are not entirely correct answers, as candidates can achieve some marks for partial correct workings. It is also useful to candidates as they can find their own errors in derivation, or calculations and can amend their answer.
- do not neglect units, eg distance is calculated and the unit for time is used, or energy is calculated and the unit of power used.
- are encouraged to be careful with the difference between “equal” and “proportional”.
- perform the full range of learning as for core physics; activities such as simple laboratory demonstrations of parallax, the location of a star in the night sky, or working with computer interactive models of an X-ray tube can significantly raise the self-confidence of the candidate.

Candidates must be reminded that every word must be clear and legible. Answers must be written in the boxes and on additional sheets.

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

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 3	4 – 7	8 – 11	12 – 15	16 – 18	19 – 22	23 – 40

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

In general, the candidates seemed well-prepared for the examination. Candidates had difficulty with recalling definitions and stating these definitions in a precise manner. This is a common issue. It was often evident that candidates did not have a clear understanding of the specific relationship between a formula and the physical setting involved, eg standing waves, isotopic half-life and sound interference.

Frequently, the candidates had difficulty developing coherent scientific arguments to justify or explain a particular example.

Option A was answered by a large proportion, although accommodation of the eye was very poorly understood, with most answers referring to eye muscles rather than the shape of the lens. Standing waves were not understood in terms of the travelling waves from which they are formed. The section on the Doppler effect and a mosquito was poorly explained and its speed was very poorly answered. The application of polarisation to liquid crystal displays was very poorly explained. Candidates frequently discussed polarisation without reference to the electric field.

Option B was also a popular option. Many candidates struggled to provide a logical outline of how atomic absorption spectra provide evidence for the quantization of energy in atoms. The method of measuring the half-life of an isotope was frequently answered in vague terms only or by giving formulae with no attempt to explain how to determine the values required. Candidates appeared unfamiliar with the law of radioactive decay.

Few candidates attempted Option C. The resolution of a CCD image was very poorly attempted, and often no response was provided. The purpose of the thermistor in the operational amplifier was often not attempted.

Option D was rarely attempted, with the candidates falling into two groups – those who understood and those who did not. The main concepts of relativity, such as simultaneity, were poorly understood. The derivation of the equation was very poorly attempted, with many beginning in inappropriate statements.

Option E was a more popular topic than C or F. Describing the apparent motion of the stars was frequently answered by explaining the cause of the apparent motion rather than describing the motion. Very few candidates could successfully explain Olbers' Paradox quantitatively or resolve Olbers' Paradox using the Big Bang model.

Option F was rarely attempted. Converting a value into binary was frequently incorrect. Many did not take note of the information supplied with the output power of an optic fibre, thus repeating given information about power dissipation rather than answering the question.

Option G was very popular. Few candidates could define the principal axis. A reduction in aperture to reduce spherical aberration was often related to a reduction in brightness of the light, not the focal point. Many candidates gave general examples of the use of lasers in medicine with no specifics.

Only 23 centres provided feedback on the G2 forms this session. These comments are very useful in the design of future examination papers and teachers are encouraged to provide timely feedback via their IB coordinator. There was general satisfaction with the syllabus coverage. 87% of centres thought the paper was of appropriate difficulty, the remaining centres thought it was too difficult. 61% of centres thought the paper was of similar difficulty to last year; 22% thought it more difficult; 13% thought it was slightly easier. 4% of centres thought the clarity of wording was poor, with most describing this as good or very good. No centres thought that the presentation of the paper was poor; most describing this as good to excellent.

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

In Option A, most candidates understood the questions on rods and cones, and could perform calculations on closed and open pipes. In Option B, radioactive decay was well done – the candidates were well prepared to handle the numerical requirements such as calculating the number of nuclei to produce a given activity. In Option C, candidates were well-prepared to distinguish digital and analogue signals, and to calculate the capacity of a DVD. Option D was only well-answered in numerical questions. Option E was generally well understood, especially stellar parallax. In option G, candidates did well in drawing ray diagrams to locate the image and could calculate the effects of sound interference.

Candidates were typically able to do algebraic manipulations of equations effectively. They showed a good understanding of ray diagrams and in general they interpreted diagrams and graphs effectively.

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

Option A – Sight and wave phenomena

1. Eye and sight (a) was answered well, although candidates should be encouraged to compare the functions rather than to list the properties of rods and then of cones. If they do not earn full marks it is often because the characteristics did not "match", eg cones see colour, but rods use dim light, rather than bright light v dim light. In (b), accommodation as change of lens shape for focussing at different distances was not appreciated.

2. Standing waves (a) was very badly answered, with few appreciating that the standing wave is made from 2 (or more) travelling sound waves. (b) was usually well attempted, with arithmetical errors or errors in the relationship between wavelength and pipe length giving any difficulty. There was a mixed set of responses to (c), from those who clearly understood to those who could not give a mathematical reason.

3. Doppler effect In (a), many candidates drew the classic diagram with wavefronts closer in front of the source and further apart behind. However, very few related this to the situation and the values given. (b) was a more difficult question with few working through to the solution.

4. Polarization (a) was either very well answered or lacking in reference to the electric field. (b)(i) was very poorly answered, with most placing the polarizing sheets on either side of the liquid crystal. Most did not indicate the position of the reflecting sheet at all. In (b)(ii), most attempted to use a formula, rather than considering the effect of the liquid crystals.

Option B – Quantum physics and nuclear physics

5. Wave nature of matter (a) was usually well answered. (b)(i) was either well answered or incorrect. (b)(ii) was very poorly answered.

6. Atomic spectra and energy states In (a), candidates rarely described absorption spectra, rather explaining emission spectra. There were very poor explanations of quantized energy states. (b) was generally well answered, although a common mistake was to have the change in the wrong direction.

7. Radioactive decay (a)(i) was well answered, as was (a)(ii). (b)(i) was poorly answered, with many referring to measurement of the loss of mass of the sample. (b)(ii) was very poorly answered. Most did not use the law of radioactive decay, as required in (b)(iii). (b)(iv) was either very well answered or very poorly answered.

Option C – Digital technology

8. Storage of information (a)(i) was well answered. In (a)(ii), most candidates understood DVD storage much better than cassette tape storage. In general, (b)(i) was very poorly explained, although some knowledge was certainly present. In (b)(ii), little explanation was given with any attempts at calculations, making marking more difficult.

9. CCDs (a) was poorly answered. Most candidates were successful in answering (b)(i), but most were not for (b)(ii). An incomplete answer was usually given to (c), considering voltage only.

10. Operational amplifier (a) was poorly answered. (b) was not understood and rarely related to the situation of a greenhouse presented in the question. (c) was very poorly answered.

Option D – Relativity and particle physics

11. Simultaneity Usually candidates gave acceptable answers to (a) but forgot that the speed of light must be constant for their statements to be true. Very few answered (b) well.

12. Light clock (a) was well answered. (b)(i) was very poorly answered, with most starting from $t' = \gamma t$ which was not what the question required. For (b)(ii), most began the curve at point 1 on the *y*-axis, but usually increased the *y*-value too rapidly towards the asymptote.

13. Fundamental interactions and elementary particles (a)(i) and (a)(ii) were well answered. Most answers to (b)(ii) used quark baryon numbers of 1 etc, not $\frac{1}{3}$. (b)(iii) was well answered by those who understood the topic. (b)(iv) was answered well by those who could successfully find the answer to (iii) despite the value being given.

Option E – Astrophysics

14. Night sky (a) was generally well answered. In (b), most explained what *caused* the apparent motion, rather than *describing* the apparent motion.

15. Stellar radiation and types In (a)(i), many were diverted by the radii given for the stars, rather than referring to absolute and apparent magnitude as the question required. Able candidates answered (a)(ii) well, but many candidates made mistakes with the powers or tried to evaluate the luminosity and radius of the sun and failed in the process. (b)(i) was mostly well answered. In (b)(ii), most could give some reasoning, but a significant minority did not attempt to determine a value for the distance to Alnilam.

16. Cosmology Most answers to (a) were not quantitative. Most could not link the CBR causatively with the Big Bang in (b). In (c), most could gain one mark in the question, but rarely gained more than one.

Option F – Communications

17. Radio communication (a)(i) was well answered. Many could not express the answer to (a)(ii). (a)(iii) was very poorly answered, with few including one whole cycle. (b) was well answered, although many candidates listed the cost of AM as an advantage, which depends on too many different options to be acceptable.

18. Digital signals Many used the graph in (a) correctly. (b) was frequently miscalculated. Few candidates were able to answer (c), giving generalised answers.

19. Optic fibres (a)(i) was well answered. In (a)(ii), many candidates were not careful to obey the law of reflection. Most failed to determine the attenuation in (b). (c)(i) was very poorly answered, with most not following the direction and answering in terms of noise or power loss. Generally (c)(ii) was very poorly answered.

Option G – Electromagnetic waves

20. Convex lenses Rarely did candidates give a precise definition in (a)(i). (a)(ii) and (a)(iii) was generally well answered. Many drew correct outer lines in (b)(i) but failed to draw the correct central cross. In (b)(ii), most could not relate spherical aberration to different focal lengths.

21. Lasers Parts (a)(i) and (a)(ii) were well answered. (b) was usually answered with a vague description of “surgery” rather than a specific and detailed use.

22. Interference of sound waves Most described the interference in (a), without giving a cause, such as path difference. Many answered (b) and (c) well.

Recommendations and guidance for the teaching of future candidates

- The practice of removing constants from equations before substituting values when a ratio is required would simplify working and reduce arithmetical errors.
- Show, outline, describe and explain are important terms used in examination questions. Candidates should be aware of the expectations of these terms.
- When asked to “show”, the student should begin with the data given to arrive at an answer rather than going backwards. The candidate should also make clear their process with annotations or explanations of equations and relationships that are used.
- Round off at the end of a string of calculations, not at each step.
- As this is a Physics examination: explain the physics involved, being precise and concise.
- Encourage candidates, if extra pages are necessary, to indicate in the exam booklet that the work is continued in an extra book, and clearly label the answer in the extra booklet with the matching question numbers.
- Use a dark pencil for drawing, and be careful to erase mistakes in drawings as the scanning does not allow easy recognition of what has been partially erased and what is a double line (eg in graph lines of best-fit). Drawing a line in a different colour is no longer useful to highlight an answer, as the scans are grey-scale.
- Candidates would benefit from developing a solid conceptual understanding of the definitions, as well as recalling the precise language involved in the definition. This can be used as a basis for solving most physics problems.
- Practice with the in depth understanding needed to connect the variables in a formula to their physical meaning would be of benefit. This can be developed by practical work, by hypothetical questions and by the study of real (often historical) experiments.
- Candidates often had difficulty with writing clear responses and developing arguments. Learning experiences that give candidates specific instruction in how to write scientifically, including citing evidence, creating a logical flow of ideas, and using provided information, would greatly enhance the students’ chances for success. Some candidates would benefit from developing the habit of using bullet points, to avoid repetition and to identify important points in their arguments.

- Although a small percentage of candidates attempted more than two options, it is always good to provide a two-option focus for candidates and to address these options in a timely manner that allows for the integration of core knowledge into the specific components of the option.

- The whole option needs to be thoroughly taught since often there are substantial marks for what might seem to be a small section in the syllabus.

- Candidates need to know what each of the Data Booklet equations represent and the correct application of each of these equations.