PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 30	31 - 43	44 - 53	54 - 63	64 - 72	73 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 26	27 - 38	39 - 47	48 - 58	59 - 67	68 - 100

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

IB Procedures for November 2011 exam session

For the most part, teachers knew the IA requirements, they used the appropriate forms and the sampling procedures were followed. Homemade 4/PSOW forms were for the most part acceptable, but a few schools forgot to include the boxes for the moderator and principal moderator's marks. Deadlines were met and there were very few procedural difficulties. The November 2011 exam session IA moderation ran very smoothly.

Comments unique to November 2011 exam session

A number of schools demonstrate excellent use of ICT. Most schools produced electronic reports and most schools constructed graphs using appropriate software. In one particular school, the teacher inserted editing comments into the student's lab report, comments that indicate the criterion, aspect and reason as well as pointing to the exact evidence for awarding the achievement level. This made moderation run smoothly, as the moderator knew exactly what aspect earned what mark and for what evidence. In contrast, there are still a few schools producing handwritten reports and sketching graphs freehand (without graph paper). The range of work quality was huge.

Many schools demonstrated detailed and consistent marking, and required no moderation. A few schools had inconsistent and unjustified marking, and these were often moderated down (although in a few cases they were marked up).

Many schools are now assigning only two investigations, each assessed by all three criteria. This is unfair to the student, as they have no opportunity to improve their work.

There now exists a body of established Design prompts for teachers that most centres use again and again. The OCC and teacher training workshops may be responsible for this positive step.

More and more teachers are giving candidates an IA checklist, and this has positive consequences in the achievement levels of the candidates. This is good practice and is encouraged. The checklist is simply a restatement of the criteria expectations.

The range of practical programs is as wide as ever while the average centre has an adequate and appropriate IA program. The practical side of IB physics is indeed being addressed.

The range and suitability of the work submitted

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

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

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

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

Candidate performance against each criterion

Design

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

Data Collection and Processing

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

There were some cases where graphs would have been relevant but candidates just made calculations. These cases cannot 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

This can be the most difficult criterion to earn full marks, especially aspect 1, and it is often over marked by the teacher. Candidates need to think beyond the given data in order to provide a justification based on a reasonable interpretation of the data. Such insight might look at the extremes of the data range, the origin of the graph, or the y-intercept for some physical meaning. Candidates might even give the overall relationship some physical interpretation (perhaps a hypothesis). Teachers need to look for this when awarding aspect 1 a complete, as moderators often had to change a “complete” to a “partial”. Finally, if candidates perform a standard and well established physics lab, and CE is assessed, then it is unlikely that they can come up with weaknesses or improvements. CE is best assessed when candidates have also designed and performed the investigation themselves.

Recommendations for the teaching of future candidates

- Candidates need a clear understanding of the IA criteria. To help with this, the teacher could give candidates a copy of a very good IA investigation; one that earned all completes.
- Candidates need to be trained in achieving the IA aspects. Group work, teacher guidance, even peer review can help but of course in such cases the teacher would not mark the IA for an IB grade on the 4/PSOW.
- It is important that when practical work is assessed that the candidate works alone. This does not mean, however, that another candidate cannot help, say, release a ball from a given height while the candidate measures the time. All measurements must come from the candidate being assessed. Occasionally moderators find identical data sets and then they are suspicious. Also, research on the Internet or in the library is not appropriate.
- Lab reports should have descriptive titles, like “How The Length of a Pendulum Affects the Period”, and not “The Pendulum”.
- Teachers that included comments on the student report or on attached sheet that stated exactly the level of achievement, and why they awarded the mark, often were not moderated up or down, as such detailed attention to assessment allows an appropriate level of marking and is usually justified by the teacher. This practice is encouraged.

Further comments

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

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

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

Paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 18	19 - 26	27 - 29	30 - 32	33 - 35	36 - 40

Standard level

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

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 35 responses from 214 centres and for HL there were 32 responses from 174 centres. Consequently, general opinions are difficult to assess since those sending G2's may be only those who feel strongly in some way about the papers. The replies indicated that the November 2011 papers were generally well received, with many of the G2's containing favourable comments. The majority of the teachers who commented on the papers felt that they contained questions of an appropriate level and were generally in line with last year's papers, although 22% found the HL paper a little easier than its predecessor. This opinion was, indeed, supported by the view of the senior examiners and backed up by the statistics. Such changes in level of difficulty can be accommodated when grade boundaries are set.

With one exception, 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 grey 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	63	138	692	48	3	73.31	0.48
2	9	21	20	893	1	94.60	0.11
3	596	191	109	43	5	63.14	0.65
4	107	108	236	491	2	52.01	0.42
5	121	53	57	712	1	75.42	0.34
6	42	795	35	70	2	84.22	0.29
7	725	139	32	45	3	76.80	0.45
8	84	90	132	636	2	67.37	0.39
9	3	9	880	50	2	93.22	0.10
10	738	63	82	59	2	78.18	0.46
11	21	94	738	89	2	78.18	0.31
12	13	805	30	94	2	85.28	0.29
13	41	652	92	156	3	69.07	0.39
14	207	45	647	42	3	68.54	0.46
15	100	215	607	19	3	64.30	0.36
16	795	22	9	116	2	84.22	0.28
17	10	56	15	861	2	91.21	0.18
18	914	10	3	14	3	96.82	0.06
19	47	240	78	575	4	60.91	0.58
20	269	205	136	327	7	28.50	0.23
21	60	36	35	809	4	85.70	0.34
22	89	733	35	85	2	77.65	0.42
23	410	202	181	148	3	43.43	0.46
24	114	716	70	38	6	75.85	0.53
25	316	437	67	120	4	79.77	0.30
26	40	26	796	80	2	84.32	0.35
27	754	24	157	7	2	79.87	0.32
28	632	129	87	85	11	66.95	0.49
29	99	526	76	241	2	81.25	0.32
30	100	242	144	451	7	47.78	0.41
31	542	196	68	133	5	57.42	0.51
32	358	21	10	552	3	58.47	0.52
33	60	780	40	61	3	82.63	0.22
34	14	740	78	104	8	78.39	0.37
35	111	156	521	154	2	55.19	0.68
36	507	85	67	274	11	53.71	0.72
37	113	588	156	86	1	62.29	0.30
38	19	826	65	28	6	87.50	0.28
39	749	111	39	35	10	79.34	0.47
40	189	22	62	662	9	70.13	0.53

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	34	113	506	264	3	55	0.16
2	102	192	572	50	4	62.17	0.51
3	186	191	464	77	2	50.43	0.46
4	168	671	42	37	2	72.93	0.32
5	423	228	201	62	6	45.98	0.59
6	75	53	273	517	2	56.20	0.45
7	27	28	58	804	3	87.39	0.15
8	124	96	274	425	1	46.20	0.43
9	249	62	234	373	2	27.07	0.37
10	395	429	76	17	3	46.63	0.64
11	12	17	814	73	4	88.48	0.17
12	35	110	56	715	4	77.72	0.25
13	865	19	10	23	3	94.02	0.10
14	85	511	155	168	1	55.54	0.44
15	227	93	530	67	3	57.61	0.45
16	208	305	96	308	3	22.61	0.25
17	198	217	181	322	2	35	0.60
18	40	448	366	60	6	48.70	0.47
19	86	57	526	247	4	57.17	0.45
20	98	646	34	139	3	70.22	0.42
21	253	209	211	242	5	27.50	0.31
22	672	155	54	37	2	73.04	0.50
23	72	66	677	102	3	73.59	0.47
24	458	220	76	160	6	49.78	0.31
25	43	642	106	126	3	69.78	0.42
26	120	533	205	61	1	57.93	0.57
27	87	236	399	189	9	43.37	0.56
28	179	384	297	57	3	32.28	0.32
29	305	120	92	395	8	33.15	0.47
30	68	684	92	70	6	74.35	0.28

Comments on the analysis

Difficulty

The difficulty index varies from about 28% in HL and 22% in SL (relatively 'difficult' questions) to about 97% in HL and 94% in SL (relatively 'easy' questions). The majority of items were in the range 45% to 75%. These statistics indicate that the students found these papers somewhat easier than in previous years. However the papers gave an adequate spread of marks while allowing all students 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 (it will be seen in the statistics that the easier questions typically have a lower discrimination index).

'Blank' response

In both papers, the number of blank responses was randomly distributed throughout the test. This may indicate that candidates had sufficient time to complete their responses, but simply 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, candidates should be able to eliminate some of the 'distractors', thus reducing the element of guesswork.

Comments on selected questions

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

SL and HL common questions

SL Question 5 and HL Question 3

The many students who opted for B were not taking into account the mass of the object.

SL Question 15 and HL Question 14

The popularity of incorrect response A indicates, perhaps, that many students knew their physics, but did not read the question carefully.

SL Question 16 and HL Question 20

The responses to this question were very evenly spread with the most common response being D, which was incorrect. This indicates a generally poor understanding of internal resistance, even amongst many of the good candidates.

8.0 V is driving a current through the external resistance when the switch is closed. So the current is 4.0 A. This current is also passing through the internal resistance which has a p.d. of 4.0 V across it. So its resistance must be 1.0 Ω.

SL Question 21 and HL Question 23

This question generated the full range of responses in almost equal measure, indicating possible confusion. The question clearly asks for the *force* experienced by Y, yet many candidates responded as if it were asking for the direction of the magnetic field at Y.

It is possible to answer this question by using first the right hand 'grip' rule, followed by Fleming's left hand rule; but candidates should have seen parallel current causing attraction and committed this observation to memory.

SL Question 25 and HL Question 34

This question was well answered although quite a few candidates immediately linked *density* to *kg* m^{-3} without carefully reading the question.

SL Question 29 and HL Question 36

This is clearly an ‘order of magnitude’ question. Candidates should be able to reason that the order of magnitude of the area involved is 23 and the order of magnitude of the power is 26. This clearly gives A as the best response.

HL Questions

Question 7

The mass of the rocket does not affect the escape speed, although it will, of course, affect the *energy* needed to escape from the Earth’s gravitational field.

Question 15

B was a popular distractor indicating that some candidates thought that being ‘in phase’ represented a phase difference of π rather than 2π.

Question 24

Far too many candidates thought that the rms value was half of the peak value.

Question 25

There were, questionably, two plausible responses to this question – A and B. Both were accepted.

As the metallic wing moves through the Earth’s magnetic field so an emf will be induced between R and P in such a direction as to move (positive) charge from R to P. This would indicate that B was the correct response.

But as a result of P being now more positive than R, it can be argued that an electric field is established from P to R. This would result in response A.

It is impossible to tell whether the confusion was due to the slightly ambiguous nature of the question or whether candidates were unable to use the correct hand to analyse the situation. But the poor showing in Q 23 would suggest it may be the latter; in which case this is an area of the syllabus that needs more attention.

Question 29

There were two correct responses to this question – B and D. Both were accepted. The *intensity* of the light has no effect on the distribution of the kinetic energies of the photoelectrons, only the wavelength.

Question 32

Far too many candidates selected response A, indicating that they had not carefully read the question.

Question 37

There is always room for debate with such questions, but it was pleasing to see that most candidates clearly identified B as the best response.

Question 40

This question was a one-step calculation based upon Q = CV. It was disappointing to see how many candidates opted for A.

SL Questions

Question 1

This is one of those facts that need to be memorized.

Question 4

Many candidates gave A as their response, indicating that they had not carefully read the question.

Question 6

C being correct would imply that B were correct, which in turn would imply that A were correct. Hence D must be the required response.

It should also be understood that the gravitational force acts on a stone throughout its flight path, so there is a corresponding acceleration.

Question 9

Since *impulse* is the *change of momentum*, both C and D are equivalent and it must be assumed they are false. This question was poorly done indicating that the candidates had not appreciated the constancy of the impulse whenever anything is brought to a halt.

Question 10

This is a recurring misconception amongst candidates. When a substance changes state the mean kinetic energy of its particles cannot change as the temperature does not change.

Question 17

Many candidates were confused by this question. Its discrimination index was high, though, showing that the better candidates chose the correct response.

Candidates are frequently asked to give the value of a ratio. And they frequently select the inverse of the correct response. In this case Y has a smaller radius than X so it clearly will have a higher resistance; so only C and D are worth considering. And since the resistance is proportional to the *cross-sectional area* of a wire D must be the correct response.

Question 18

Candidates frequently find it difficult to convert between Joules and Electronvolts although they know that there is a factor of 1.6×10^{-19} between them. Joules are useful for everyday laboratory measurements of energy. Electronvolts are used when we are referring to very small quantities of energy associated with transitions with an atom. So clearly B is the only possible correct response.

Question 22

A worrying number of candidates chose the response B. Perhaps they had been taught that 238 was the *mass* number and not been alerted to the fact that it can equally well be referred to as the *nucleon* number.

Question 24

Radioactive decay is noteworthy inasmuch as its rate cannot be affected by physical parameters (as is suggested by B, C and D). It answers only to the call of probability. Introductory lessons on the topic often miss the enigmatic nature of the cause of radioactivity and move directly to its products. Clearly the more dice are thrown the more sixes are likely to be scored; so the only possible response is A.

Question 28

Many candidates chose B as their favoured response and a worrying number chose A or D. One can only assume that they understood *albedo* as 'ability to absorb radiation' – or that they did not read the question stem carefully.

Recommendations and guidance for the teaching of future candidates

Candidates should make an attempt at every item. Where they cannot provide the correct response, then they should always choose that option which, to them, appears to be most likely. It should be emphasized that an incorrect response does not give rise to a mark deduction. Frequently responses can be eliminated, either because they are transparently absurd, or because two responses are logically equivalent.

When preparing the students for Paper One it can be a good strategy to invite the students to explain why the distractors are wrong (rather than why the correct response is right). This works better for some questions than others, but encouragement to disprove a theory or idea is good scientific training.

The stem should be read carefully. It appears that some candidates do not read the whole stem but rather, having ascertained the general meaning, they move on to the options. Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important.

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

This Guide does invite the students 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 students to occasionally memorize information.

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

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 11	12 - 22	23 - 33	34 - 43	44 - 52	53 - 62	63 - 95

Standard level

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

Just over 30 centres returned G2 forms and comments for each of the HL and SL papers. The information given to awarders by these forms is of great importance and the awarders urge centres to submit this information.

At both levels there was a considerable satisfaction with the papers, with 94% (83% at SL) finding the level of difficulty appropriate, 62% (57% at SL) regarding the paper as being of a similar standard to that of the previous year's paper. All respondents found the clarity of wording and the presentation of the papers to be either good (70%) or satisfactory.

The statistics of the examination generally agree with these perceptions. The mean mark on the components rose very slightly compared to November 2010 (with very similar standard deviations).

General comments

Standard pieces of bookwork and proofs are often poorly remembered and negligently reproduced. Marks can be reduced very significantly by failures in this respect.

Candidates need to make it clear to examiners when work is presented other than in the standard box allowed for the answer. Work on supplementary sheets or elsewhere in the answer booklet can be viewed by the examiner on-screen but if no indication of its presence is given to the examiner it may be overlooked.

Candidates still misunderstand the distinctions between command terms. In particular, even good candidates do not give sufficient explanation in the case of questions that ask for a determination or invite candidates to "show that" some value can be obtained.

Candidates continue to make large numbers of unit errors and significant figure errors throughout the paper. They are failing in one of the important technical areas of the subject.

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

The examining team identified the following areas:

- Free-body diagrams
- Movement of charge in conductors and insulators
- Orbital motion, especially escape speed
- Explanations of the electron-in-a-box model
- Potential divider theory
- Enhanced greenhouse effect

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

It was pleasing to see the following skills demonstrated:

- Nuclear physics calculations
- Mechanics calculations
- Electricity calculations

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

There were many common questions between SL and HL. The comments below are arranged in the order that the questions appeared in HL.

Section A

A1 [HL and SL] Data analysis question

The context for this question was the variation with water depth of surface water waves.

a) (i) and (ii) The absolute uncertainty calculation was well done and explained by many. This is evidently a part of the syllabus that is now well understood. However a small minority went on to spoil the answer by careless and incorrect drawing of the error bars on the printed graph.

b) (i) Lines were often poor with a low standard of draughtsmanship. A large number of candidates drew a straight line that cannot accommodate all the error bars. They should learn that a “line of best fit” is not the same as a “straight line of best fit”.

(ii) Comments usually focussed on the origin issue. There were two marks available and candidates frequently scored only one because of this failure to give a complete answer.

c) This was often well done, but a minority simply wrote $c \propto d^{0.5}$, thus repeating the question and gaining no credit. It was not clear if these were their proposed axes.

d) (i) This meaning of the term systematic error was obviously well understood but candidates sometimes used circuitous ways to express it. Examiners often had to infer the candidate's understanding.

(ii) Marking was generous here. Any valid statement that arose from the earlier answer or could have arisen was allowed.

A2 [HL] and B1 Part 2 [SL] Internal energy

a) The distinction between concepts of internal energy and temperature was often incompletely expressed. Any clear reference to molecules or particles, etc. was very commonly omitted. Discussions of the meaning of temperature were weak with much misunderstanding.

b) Examiners were looking for clear discussions of the change in average kinetic energy of the molecules when the higher energy constituents have been removed but there was lack of clarity both in the understanding and in the writing here.

A3 [HL and SL] Radioactivity and nuclear fusion

a) **[HL only]** (i) There were two marks available but candidates usually gained one mark because they gave only one point or because two points were made but one of them was poorly expressed. The unstable nature of the radioactive material was commonly seen, but the clear description of the emissions rarer.

(ii) Fusion descriptions were often vague and did not address the issue that it is nuclei that fuse rather than atoms or molecules.

b) **[HL]** Many candidates gave good and clear description of their work and worked competently to arrive at the correct answer. Failing solutions featured work that was attempting a solution using integer values of half-life with a final interpolation to determine the answer; this cannot score.

[SL] This was well done, SL calculations can only involve integer numbers of half lives and candidates are well versed in handing these.

c) **[HL only]** (i) This was universally well done by all but a handful of very weak candidates.

[Hl and SL] (ii) A good number scored all 3 marks with clear, concise work. A significant minority could not get further than an evaluation of the number of fusions per second (which scored some credit).

[HL and SL] (ii) Most candidates failed to read the question and did not give problems associated with *sustaining* the reaction. They gave responses that dealt with the initial problems of fuel supply or, far too frequently, with the treatment of the supposed radioactive products. These latter candidates were confusing fusion with fission.

A4 [HL] Gravitation

a) Few noticed that this was an "explain" and ignored the aspects of the question that involve the starting point for the spacecraft or its end point. A substantial number described the term simply in terms of one mass escaping another (irrespective of size or planetary status).

b) (i) Many candidates scored full credit for this simple substitution and evaluation.

(ii) Those who began by equating the kinetic energy per unit mass to the gravitational potential were usually able to work through to a complete solution. Candidates floundering and equating centripetal force or acceleration were unable to score credit.

c) Most were able to take this comparatively straightforward problem through to a correct solution. There was some credit available for those who could not determine the time to fall to the ground correctly (some candidates using a value of 10 N kg^{-1} for *g*).

A5 [HL] Charge-coupled devices

a) Too many candidates are still unable to define quantum efficiency accurately.

b) Candidates are now well versed in carrying through calculations involving the magnification and efficiency of a CCD. Major errors on this occasion involved the confusion of area and distance in the definition of magnification.

c) The advantages of the digital *camera* were often stated well, but there are many candidates who fail to read the question and dwell on the advantages of any digital system over analogue. This was not what was required.

Section B

B1

B1 Part 1 [HL] and B3 Part 1 [SL] Greenhouse effect

Throughout this question there was much evidence that candidates confuse the greenhouse and the enhanced greenhouse effects.

a) Candidates failed to give a good account of the mechanisms at work. They have only a sketchy idea of how the greenhouse gases (which they frequently do not mention) act to trap energy. The wavelength shift and the reasons for it are often ignored.

b) (i) – (iv) Although the question was laid out in a sequential way, candidates did not take advantage of this and gave bitty responses that failed to show the progression from the observed absorption frequency, through the resonance effect in the water molecules, to the greenhouse effect itself. Examiners felt that candidates should take more opportunity to read and understand the whole of a question and its implications before embarking on an answer.

c) This was well done by many candidates. However, a significant number spoiled the answer in its entirety by failing to make clear the similarity in magnitude at the end. This was a “show that” and candidates must endeavour to make clear to the examiners the extent to which the answer agrees with the data. There was an unfortunate error in a datum for the question, but, as the data were still consistent, no candidate was disadvantaged (indeed, no candidate or centre remarked on the problem).

B1 Part 2 [HL only] Electromagnetic induction

a) (i) Considerable latitude was available to candidates but this still did not prevent the careless few from drawing sine waves or very careless graphs from which examiners could determine very little.

(ii) Many were able to recognize that the phase of their graph in (ii) should be the same as or π out of phase with the graph drawn in (i).

b) The determination was reasonably straight forward, but some candidates became confused with the data and were apparently unable to cope with SHM ideas and induced emf ideas at the same time.

c) Solutions here were muddled by many. It was common to see the candidate focus on either the change in amplitude or the change in frequency, rarely both.

B2

B2 Part 1 [HL only] and B1 Part 1 [SL only] Mechanics

a) As in the May 2011 examination, the force diagrams were very poor indeed. Candidates need to be aware that examiners are interested in the direction of lines (which should be accurately drawn), the labels indicating the meaning of the lines (which should not, where possible, be symbols alone), and the length of the lines (which should reflect the relative size of the forces). In all three areas of this question, candidates were very negligent with only a handful of completely correct diagrams in the whole of the marking.

b) Explanations here were very confused. Often candidates talked in terms of their poor diagrams from (a). It was rare to see a convincing argument that discussed the horizontal forces acting (and cancelling) leading to zero acceleration and hence constant velocity. Arguments that could be interpreted as dealing equally with horizontal or vertical forces scored poorly.

c) This was well done by many.

d) Candidates showed a good level of competence with this part, but it was quite rare to see a wholly correct solution. Many were able to carry out the first or second halves of the problem but could not successfully complete the whole.

e) (i) and (ii) These were well done by many.

f) Explanations were again confused with a lack of clarity in the answers. Candidates should work to produce a logical answer. The suggestion that velocity is a vector and the change in direction leads to acceleration was often missing or weakly expressed.

B2 Part 2 [HL] Resolution

a) (i) There were many incorrect answers to this simple question, the most frequent incorrect response was “interference”, however “refraction” and “reflection” were also seen.

(ii) Some candidates described the Rayleigh criterion in words, others in a diagram. Full credit could be obtained from either, well expressed, and there were many candidates who scored both marks.

b) (i) A two-source neon sign was an unusual context for a resolution question and it defeated weaker candidates who could work out the appropriate resolved angle for resolution but could not then determine what was happening in this case.

(ii) This standard diffraction problem was carried through more happily by many.

B2 Part 2 [SL] Renewable energy

a) (i) The interpretations of hydroelectric power seem to be very wide and examiners allowed some latitude including permitting wave energy as a hydroelectric method.

(ii) Having chosen a power production method, most candidates were able to describe it, but were poor at stating the energy changes to be observed in it. Wave techniques were particularly poor in this respect.

b) (i) Inevitably, many candidates omitted the factor of two even though this was spelt out clearly in the question

(ii) The standard error here was to forget that the relevant height change is half the difference between high and low tides.

c) There were many good answers for the disadvantages of wind power. Candidates were obviously well versed in this.

B3

B3 Part 1 [HL] and A2 [SL] Electricity

a) (i) About half of the candidates drew an arrow pointing towards the nucleus, forgetting that the direction of the electric field is the direction in which a positive charge moves.

(ii) The standard calculation was well done with only some ambiguity about the final unit.

b) Although many scored the maximum two marks here, only few picked up all the marking points and were content to dwell on the presence or absence of free electrons in the materials.

c) (i) Well done by many.

(ii) Almost all were able to calculate the cross-sectional area of the conductor in a straightforward question.

d) (i) Diagrams were poor with few being able to draw a potential divider circuit with both meters in appropriate positions. A large number of candidates devised circuits that did not allow the current in the lamp to vary, and a similar number had little idea where the meters need to be placed. A significant number drew circuits in which the lamp would not light at all.

(ii) Too many *I-V* graphs for the lamp showed a straight line although almost all graphs went through the origin.

e) This question was poorly done with many having no idea how to begin. Essentially, candidates needed to show that the range of p.d. across the lamp would be 1.9 V to 6.0 V through appropriate use of $V=IR$. This was, however, beyond many.

B3 Part 2 [HL] Properties of gases

a) The instruction to “use data from the graph…” was largely ignored and candidates attempted to justify their choice on physical grounds. This scored few marks given that the choice in these cases was usually incorrect. Examiners were expecting read-offs from the graph and an evaluation of pV (twice was allowed, but three times would be better).

b) Marks were low here. Candidates seemed at a loss, whereas if the question had simply referred to the work done in one process (as in previous papers) the scores would have been higher. Even for those who were able to progress, answers were often incorrect because the candidates failed to spot that a false origin was in use (although if counting squares of the enclosed area only had been carried out, this would not have mattered).

c) Candidates now appear to understand the demands of a question such as this. There were many competent and complete answers with a correct determination of the temperature change.

d) Candidates often described what the de Broglie wavelength is, or gave an equation for it, but rarely (as the markscheme and the mark allocation required) both.

B3 Part 2 [SL] Electric motor

a) (i) The free-body drawing was poor. Similar faults to those found in B2 Part 1 [HL] were present here too.

(ii) The calculation was reasonably attempted by about half the candidates.

b) (i) and (ii) The power calculation and the determination of efficiency were acceptably done.

B4

B4 Part 1 [HL] and B2 Part 1 [SL] Wave motion

a) (i) Just over half the candidates understood the direction of movement of the particle.

(ii) It is hard to think of a simpler question at this level of examination; nevertheless, candidates managed to draw the wavelength poorly and ambiguously.

b) (i) Well done by many.

(ii) As in (a)(ii) the drawings were poor and scrappy. Examiners had to give much latitude to the position and wavelength of the wave.

c) (i) Although about 25% of candidates could not proceed beyond calculating ω the remainder were able to substitute into and evaluate the equation correctly.

(ii) Several misapprehensions appeared: Candidates did not use the value for kinetic energy (ke) that they had calculated a few moments earlier, they did not recognize that the ke is always positive, they did not recognize the relationship between the periodic time of the oscillation and the periodic time of the variation in ke.

d) (i) Drawings often showed a change in amplitude or a change in wavelength, but rarely both.

(ii) Explanations were weak in general. It was quite common for a written answer here to consider a change in amplitude or wavelength that had not been drawn in (i).

B4 Part 2 [HL only] Atomic spectra

a) (i) Roughly one-half of all candidates were able to calculate the energy correctly.

(ii) Arrows often identified the correct energy change but were drawn in the wrong direction.

b) Candidates, who attempted this question, frequently left the final two parts blank, making no effort to answer the questions.

(i) The significance of the integers in the appropriate equations was lost on candidates and they failed to show how these numbers give rise to energy levels that are quantified in the theory. Too often, examiners were confronted with confused and incorrect statements about the electrons (rather than their energy levels).

(ii) Examiners only rarely saw logical and systematic attempts to relate the wavefunction to the electron-in-the-box model. As in the previous part, candidates had regurgitated facts that they knew about the theory, rather than clear answers to the question.

Recommendations and guidance for the teaching of future candidates

Candidates should be encouraged to read questions carefully and to think through the consequences of the question and the way in which it has been laid out. There is a continuing need for better presentation of work.

Again there were many instances of candidates writing answers in unexpected places. Candidates are strongly advised to inform examiners clearly when an answer is written other than in the scanning box or on a supplementary sheet.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 20	21 - 25	26 - 31	32 - 36	37 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 6	7 - 11	12 - 15	16 - 19	20 - 23	24 - 40

General comments

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

The feedback from teachers on the G2 forms for SL and HL is summarized as follows. (However, it should be realized that fewer than 20% of centres submitted G2 forms.)

Standard Level

- 70% found the paper to be of a similar standard to last year, and 30% a little more difficult. Overall, 90% found the paper to be of an appropriate standard and 10% thought it too difficult.
- About 60% found the clarity of wording satisfactory and 40% found it good.
- About 70% found the presentation satisfactory and about 30% found it good.
- The most popular options were A (Sight and wave phenomena), G (Electromagnetic waves), B (Quantum physics and nuclear physics) and E (Astrophysics). Students chose these four options in roughly equal numbers.

Higher Level

- About 90% found the paper to be of a similar standard to last year and 10% a little more difficult. Overall, apart from one centre who found it too difficult, all found the level of difficulty appropriate
- About 70% found the clarity of wording satisfactory, and 30% found it good.
- About 75% found the presentation satisfactory and 25% thought it was good.
- The most popular options were G (Electromagnetic waves), E (Astrophysics) and H (Relativity) in roughly equal numbers. There was a marked absence of scripts in the options F (Communications) and J (Particle physics). Option I (Medical physics) was also underrepresented.

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

- Role of rod and cone cells in low light conditions
- Calculations on diffraction and resolution
- Aspects of the photoelectric effect
- Alpha scattering
- Measurement of half-life
- Definition of parsec
- Calculations involving ratios
- Optical fibre calculations
- Operational amplifiers
- Wedge films
- Simultaneity in relativity
- Particle physics in general and particle accelerators in particular
- Providing sufficient depth and detail in questions with a mark allocation of more than one mark. This was particularly true in those questions involving the action verbs “explain”, “discuss” and “describe”.

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

Simple mathematical calculations were often done well by the majority of candidates. In fact, it was good to see that candidates were able to choose the correct formula and substitute in it correctly. Many candidates appeared well prepared and able to produce some excellent answers that showed a good understanding of the concepts, particularly in options A, E, and G.

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

SL only

Option A – Sight and Wave phenomena

A1 Photopic and scotopic vision

In (a) many candidates confused colour vision with low light conditions and in (b) they were unable to make the link between the two; they did not appreciate that rod cells are more responsive to low light and to green light than red light.

A2 Organ pipe

There was some confusion with the question in terms of minimum displacement and antinodes. The examiners therefore accepted labelled positions either at the centre or ends of the pipe.

Many candidates tied themselves in knots in the calculation in (b).

A3 Diffraction and polarization

Intensity distributions were usually drawn well but many forgot the factor of two in the calculation of the width of the central maximum.

In (b) the resolution calculation proved difficult for many candidates with much confusion as to what angles and distances to use.

Many candidates answered part (c) on polarization well.

Option B – Quantum Physics and Nuclear Physics

B1 The photoelectric effect

Many candidates misunderstood the question in (a)(i) and/or did not appreciate that the question was asking for experimental detail.

In (b) graphs were often correct but many candidates forgot to transform the equation in (ii) and/or failed to mention the work function/threshold frequency. Many forgot the electron charge in (iii).

Calculations of the de Broglie wavelength in (c) were often correct.

B2 Alpha particles

Many candidates seemed to be unfamiliar with calculations involving the closest distance of approach of alpha particles on scattering experiments.

Even fewer candidates had any idea as to how a half-life of several thousand years is measured. Most thought that a graph of activity against time should be plotted!

Option C – Digital technology

This was not a popular option and was generally very low scoring. The examiners often had the impression that the option was attempted as a last ditch choice.

C1 The compact disc (CD)

This question was generally the only question that was answered with any confidence.

C2 The charged coupled device (CCD)

Nearly always answered badly.

C2 The operational amplifier

This question is identical to question F3 in option F and the reader is referred to the comments in that question.

Option D – Relativity and particle physics

D1 Simultaneity and length contraction

This question is identical to parts of question H1 in option H and the reader is referred to the comments in that question.

D2 Electrons and the weak interaction

This question is identical to question J1 in option J and the reader is referred to the comments in that question.

SL and HL combined

Option E – Astrophysics

E1 Stellar distances and stellar properties

In (a) lines to represent the main sequence were often extended too far at the extremities. The definition of the parsec in (b)(i) was often given as being equal to 3.26 ly; one AU was rarely mentioned and in (ii) units were often incorrect.

Detail was often missing in (c) in the account of the parallax method for measuring stellar distance with many candidates thinking that a diagram was sufficient to answer the question.

The calculations in (d) were often done well as was the drawing of the evolutionary path in (e) [HL only].

E2 Development of the universe

In (a) many candidates were able to make the link between red-shift and the expansion of the universe but not many were able to give a correct definition of critical density in (b)(i). As such many candidates tied themselves in knots in (ii), a discussion of the future development of the universe. However, most candidates appreciated that the existence of dark matter made it difficult to get an accurate value for the density of the universe.

E3 [HL only] Hubble's law

All parts of this question were often answered well except for candidates who had problems with units of the Hubble constant and/or those who did not realize that Hubble's law refers to galaxies.

Option F – Communications

F1 Modulation and bandwidth

Most candidates could correctly distinguish between a carrier and signal wave but few had any clear idea of frequency modulation. The bandwidth calculation also defeated many candidates.

F2 Digital transmission of information

Parts (a) and (b) were often answered reasonably well but the calculation involving the optical fibre defeated most candidates.

F4 [HL only] The operational amplifier

This was a very poorly done question with students unable to score many marks other than for deriving an expression for the gain. The concept of a virtual earth was rarely understood and the use of an op-amp as a comparator even less so.

Option G – Electromagnetic waves

G1 The electromagnetic spectrum

Both parts of this question were often answered well.

G2 The compound microscope

Very few candidates knew the textbook derivation in (a) of the expression for the angular magnification at the near point. However, the ray diagram and calculation in (b) were usually done well and most candidates had a good understanding of spherical and chromatic aberration.

G3 Two source interference

It was appreciated by the senior examining team that diffraction effects on double slit interference is not on the present syllabus. In view of this wide latitude was given to candidates' answers to part (a) of this question. As such it was felt that no candidates were disadvantaged.

G4 [HL only] Wedge films

Candidates gained marks on part (a) outlining how wedge films are produced but few in (b) were able to explain the effect of increasing the wedge angle on the fringe separation.

G5 [HL only] X-rays

There was often confusion between the formation of the continuous region of the spectrum and the characteristic spectrum in (a). The calculation of the minimum wavelength in (b) was often done correctly.

HL only

Option H – Relativity

H1 Special Relativity, simultaneity and length contraction

Many candidates knew what an inertial reference frame and correctly identified the other postulate of special relativity in (a). However, answers to (b) were very varied. A common misconception was to assume that the differences in the viewpoints of Vladamir and Natasha is due to the time it takes the light from the lamps to reach them whereas it is the time taken by signal to reach the lamps that is the key.

In (c)(i) it was common to come across the inverse of the proper length as the answer and in (ii) many candidates thought that Natasha measures the proper length because she and the table are in the same reference system rather than because Natasha is at rest with respect to the table. It is worth pointing out to candidates that the table is in every reference system!

In (d) the twin paradox and its resolution were understood by many candidates. However, in the final parts of this question, the same could not be said for the decay of muons as evidence for time dilation and length contraction. Answers were often muddled and confused and too often no reference was made as to which coordinate system a particular time or length referred even though calculations to (e)(i) and (ii) had been done successfully.

H2 Relativistic energy and momentum

Many candidates struggled or did not attempt this question. The main reason for the struggle, as in past examinations, was the candidates' inability to handle units such as MeV c^{-2} such that they often became lost in pointless unit conversions.

H3 The principle of equivalence and red-shift

There were many good answers to part (a) of this question but not to part (b) where candidates could often not make the link between red-shift and time.

Option I – Medical physics

I1 Sound Intensity levels

Definitions of intensity and intensity level were often correct. However, part (b) in which the relation between loudness and intensity was tested, was very poorly answered. Clearly this is an area not well understood by many candidates. The problem in (c) was often answered well.

I2 Ultrasound imaging

Not many candidates in (a) had a clear understanding of how ultrasound is produced and in (b) many answers referred to the harmful nature of x-rays rather than their inability to image tissue and muscle.

Parts (c) and (d) were usually answered well. However, this was not the case for (e) in which few candidates could sensibly relate choice of frequency to depth of organ beneath the skin with reference to attenuation and resolution.

I3 Dose equivalence

Most candidates knew the correct definition for absorbed dose but in (b) not many really understood the significance of the quality factor.

It was pleasing to note some complete solutions to the reasonably involved problem in (c).

Option J – Particle physics

There were many poor answers to this option.

J1 Electrons and the weak interaction

Overall this was the best answered question in the option. The parts that caused difficulties were (e)(ii) in which units were a problem and (e)(iii) in which understanding was a problem.

J2 Particle Accelerators

There were few answers of any worth to this question. The principle of operation of the cyclotron is clearly not understood by many candidates.

J3 The standard model

Most candidates were able to make a reasonable attempt at (a) and (b) but the concept of deep inelastic scattering caused problems in (c).

Recommendations and guidance for the teaching of future candidates

Recommendations from the examination team included the following ideas:

- Candidates should learn to give accurate and unequivocal definitions of physical quantities.
- Candidates should be given more opportunities during the course to practice examination style problems, look at past papers and markschemes.
- Candidates should be provided with, and given assistance with, the list of command terms as specified in the syllabus. It is clear that many candidates do not recognize the difference between, for example, “state” and “explain”.
- When using a diagram to help answer a question, candidates should be encouraged to pay attention to the precision of the diagram. This is particularly true of ray diagrams, as many candidates failed to use even a sharp pencil and / or a ruler.
- Enough time should be devoted to cover in depth the Options chosen.

- Candidates should be discouraged from studying options on their own. There was evidence that this was done for this examination with options D and J. Reading popular books on relativity, particles and strings is commendable and is to be encouraged whenever possible. However, this on its own does not provide enough preparation for the examination.