PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-31	32-42	43-53	54-63	64-74	75-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-30	31-41	42-52	53-63	64-73	74-100

Standard level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-13	14-16	17-18	19-21	22-30

IB multiple choice physics papers are designed to contain conceptual questions rather than calculation-type questions. This approach, emphasizing the qualitative rather than the quantitative, is based on the view that the MCQ format is suited to testing conceptual understanding, while calculations can be better assessed in questions in Papers 2 and 3. Calculators are thus neither needed nor allowed in Paper 1. The papers are designed to have a range of difficulty of questions and reasonable topic coverage. A proportion of questions are common to the SL and HL papers, and the additional questions in HL tend to be of a somewhat higher level of difficulty.

The November 2003 papers were very well received and the comments were overwhelmingly positive. 63% of the teachers who commented on Paper 1 felt that it was of a similar standard to that of 2002 and 37% thought it a little, or much, more difficult than previously. 75 % felt that the level of difficulty was appropriate whilst 25% thought that the paper was a bit too difficult. Most felt that the coverage of the syllabus was good (58%) or satisfactory (32%) and that the clarity and wording of the paper were good (53%) or satisfactory (37%). The presentation of the paper was thought to be good (80%) or satisfactory (20%).

The Form G2, available from the *Vade Mecum*, is used to comment on examination papers and teachers are encouraged to submit these forms as they are valuable feedback to the examining team and play an important role in setting grade boundaries. We thank schools and teachers who may have commented on particular questions on the G2 forms. All these individual comments are discussed at the grade award meeting.

Statistical analysis

The overall performance of candidates and how they performed on the various questions can be usefully illustrated by the statistical analysis of responses. These results are given in the table below, SL Paper 1 Item Analysis. 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 an asterisk (*). The *Difficulty Index* (perhaps better called facility index) is the percentage of candidates who correctly answered the question. A high index thus indicates an easy question, and the table has been presented in the order of difficulty from the easiest to the hardest question. The *Discrimination Index* is a measure of how well the question discriminated between better and weaker candidates. A higher value of discrimination index indicates that a greater proportion of the better candidates correctly answered the question compared with the weaker candidates.

SL Paper 1 Item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	192	154	124*	64	4	23.04	.18
2	69	129*	266	73	1	23.97	.18
3	297*	168	66	7		55.20	.62
4	33	188*	81	236		34.94	.40
5	327*	61	16	132	2	60.78	.23
6	129	211	158*	40		29.36	.33
7	70	241*	159	68		44.79	.45
8	103	314*	60	61		58.36	.29
9	252	162*	72	51	1	30.11	.35
10	11	27	430*	70		79.92	.30
11	72	330*	76	58	2	61.33	.26
12	101	17	3	416*	1	77.32	.24
13	58	349*	43	87	1	64.86	.57
14	28	71	354*	85		65.79	.43
15	306*	126	37	67	2	56.87	.55
16	86	155	133	163	1	24.72	.14
17	25	336*	49	123	5	62.45	.31
18	23	449*	44	22		83.45	.29
19	382*	8	106	38	4	71.00	.34
20	362*	75	50	49	2	67.28	.40
21	180	46	257*	52	3	47.76	.42
22	222*	175	78	60	3	41.26	.31
23	30	75	140	289*	4	53.71	.46
24	143	78	49	267*	1	49.62	.07-
25	115	213*	57	149	4	39.59	.32
26	107	274*	100	55	2	50.92	.49
27	73	136	254*	69	6	47.21	.27
28	76	214*	123	123	2	39.77	.47
29	156	87	57	234*	4	43.49	.32
30	113	92	269*	52	12	50.00	.53

Comments on the analysis

Difficulty Range. It will be noted that the difficulty index has a very wide range. The index varies from about 23 (a hard question with only 23% of candidates giving the correct answer) to about 83 (an easy question with 83% of candidates giving the correct response).

Discrimination. The discrimination index is satisfactorily high overall. The index reaches values as high as 0.62. For one item, (number 24) the Index is as low as –0.07. This is a satisfactory outcome, indicating that, on the whole, the paper discriminated reasonably well.

Comments on selected questions

For the most part, the questions were judged to be good, in that they were conceptual, well formulated and suited to the MCQ format. 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. Thus comment will only be given on selected questions, i.e. those that illustrate a particular issue or where a problem was identified. Note that questions on which students performed well are not in general discussed, but can be identified from the analysis above. Detailed discussion is reserved for questions that students found difficult or where misconceptions are identified by popularity of distracters. Thus most of the comments below identify conceptual difficulties that students have with certain physical situations, and hence should serve as feedback for teaching. Each of the comments below resulted from discussions in the Grade Award Meeting.

It should be noted that the use of boldface is intended to make it easier for the student to understand the question. It is, therefore, used sparingly. Candidates should appreciate that all words in all items are of importance.

Question 1

This question proved to be difficult for candidates. Options A and B were intended to be approximate values for the diameter of a nucleus and for the diameter of an atom (if the unit is the metre). These Options proved to be very popular and were powerful distractors.

Question 2

With a difficulty index of approximately 24%, this question is worthy of comment. It is a popular misconception amongst candidates that the coulomb is a fundamental unit. Consequently, Option C was the most popular option. The point that it is the ampere, not the coulomb, that is the fundamental unit needs to be emphasised.

Question 4

It might have been better to state in the question that the resultant force is on the object. However, the most usual response (Option D) indicates that candidates thought that a particle executing circular motion is in equilibrium! Clearly, this is an important teaching point.

Question 9

A good question with a high discrimination, although the difficulty index is only 30%. All too frequently, candidates fail to appreciate the vector nature of momentum.

Question 18

Most candidates found this question easy with 83% answering it correctly. An appreciation of graphical analysis is not an easy topic for candidates and credit must be given to teachers for their work in this area.

Question 21

This question had a difficulty index of 48% and a high discrimination of 0.42. This would indicate that more able candidates answered the question correctly. Weaker candidates frequently opted for Option A, illustrating the popular misconception that it is positive charge that can move on the rod or cloth. It is expected that candidates would realise that it is the electrons that are mobile.

Question 24

The discrimination index for this question is – 0.7. In some circumstances, this low index would indicate an unsatisfactory question. This is not the case here. Many candidates opted for an answer based on the gradient of the graph. This is quite wrong. The resistance of a component is defined as the ratio of voltage and current at that particular value of voltage.

Question 26

It may have been desirable to state in the stem of the question that the aluminium foil is held horizontally. However, judging by the response of candidates, there was no apparent problem as regards the orientation of the diagram.

Question 30

This question had the highest number for those candidates who failed to give an answer. The discrimination and difficulty index were quite satisfactory. It is likely that these candidates lacked the time to complete the Paper.

Areas where students had difficulties and areas where they were well prepared

It is difficult to generalise in a broad-based paper such as Paper1 over areas of difficulty or where students were well prepared. The comments on the individual questions and the percentages of student selections for each question should provide enough information about student difficulties and areas where they were well prepared. Some candidates struggled with the conceptual nature of these multiple-choice questions but it is encouraging to note from the statistics that many candidates did remarkably well.

Recommendations for the teaching of future candidates

The nature of the questions highlights the need to emphasize conceptual understanding of the basics. Qualitative reasoning about physical systems should be taught in addition to formula-based problem-solving.

Even though it may appear redundant to state this in this report, students need constant encouragement and reminders to read the questions carefully. Often, incorrect answers are given simply because the student has gone through the question too quickly and missed a crucial word that prevented him/her from getting the right answer. Examiners attempt to make questions as clear and as concise as possible. This implies that all wording is of importance.

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-15	16-20	21-23	24-27	28-30	31-39

IB multiple choice physics papers are designed to contain conceptual questions rather than calculation-type questions. This approach, emphasizing the qualitative rather than the quantitative, is based on the view that the MCQ format is suited to testing conceptual understanding, while calculations can be better assessed in questions in Papers 2 and 3. Calculators are thus neither needed nor allowed in Paper 1. The papers are designed to have a range of difficulty of questions and reasonable topic coverage. A proportion of questions are common to the SL and HL papers, and the additional questions in HL tend to be of a somewhat higher level of difficulty.

The November 2003 papers were very well received and the comments were overwhelmingly positive. 73 % of the teachers who commented on Paper 1 felt that it was of broadly similar standard to last year's while 13% thought it to be more difficult. 84% of all respondents felt the difficulty was appropriate while 11% thought the level was too difficult. All respondents rated the paper as good (63%) or satisfactory (27%) as far as syllabus coverage was concerned. All thought the clarity of wording of the paper was either good (63%) or satisfactory (27%). All also felt that the presentation of the paper was good (78%) or satisfactory (22%).

The Form G2, available from the *Vade Mecum*, is used to comment on examination papers and teachers are encouraged to submit these forms as they are valuable feedback to the examining team and play an important role in setting grade boundaries. We thank schools and teachers who may have commented on particular questions on the G2 forms.

Statistical analysis

The overall performance of candidates and how they performed on the various questions can be usefully illustrated by the statistical analysis of responses. These results are given in the table below, HL Paper 1 Item Analysis. 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 an asterisk (*). The *Difficulty Index* (perhaps better called facility index) is the percentage of candidates who correctly answered the question. A high index thus indicates an easy question, and the table has been presented in the order of difficulty from the easiest to the hardest question. The *Discrimination Index* is a measure of how well the question discriminated between better and weaker candidates. A higher value of discrimination index indicates that a greater proportion of the better candidates correctly answered the question compared with the weaker candidates.

HL Paper 1 Item Analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	136	135	97*	39	3	23.65	.21
2	1	7	378*	24		92.19	.11
3	13	80	60	257*		62.68	.56
4	259*	37	14	98	2	63.17	.30
5	30	201*	35	143	1	49.02	.37
6	106	228*	18	57	1	55.60	.44
7	37	220*	107	45	1	53.65	.57
8	25	335*	33	16	1	81.70	.23
9	12	31	16	351*		85.60	.33
10	15	16	240	136	3		.00
11	55	241*	62	51	1	58.78	.48
12		7	70	333*		81.21	.32
13	81	69	214*	43	3	52.19	.58
14	58	8	1	343*		83.65	.24
15	45	13	346*	5	1	84.39	.16
16	13	327*	13	56	1	79.75	.29
17	18	24	318*	50		77.56	.39
18	296*	35	47	32		72.19	.36
19	22	76	148	162*	2	39.51	.55
20	66	106	29	208*	1	50.73	.62
21	24	301*	24	58	3	73.41	.37
22	35	42	268*	65		65.36	.41
23	183*	31	166	30		44.63	.27
24	33	23	50	303*	1	73.90	.44
25	232*	100	41	37		56.58	.23
26	313*	44	26	27		76.34	.38
27	74	35	277*	22	2	67.56	.44
28	43	166	169*	29	3	41.21	.28
29	155	42	29	183*	1	44.63	.01-
30	64	194*	34	118		47.31	.39
31	81	269*	34	24	2	65.60	.39
32	15	35	55	303*	2	73.90	.40
33	26	252*	84	46	2	61.46	.47
34	67	38	183*	121	1	44.63	.34
35	40	210*	85	72	3	51.21	.61
36	175*	97	71	66	1	42.68	.27
37	82	46	50	231*	1	56.34	.51
38	151	163*	48	44	4	39.75	.26
39	53	19	305*	32	1	74.9	.28
40	202*	35	130	41	2	49.26	.33

Comments on the analyses

Difficulty Range. It will be noted that the difficulty index has a wide range. The index varies from about 23 (a hard question with only 23% of candidates getting it right) to about 92 (an easy question with 92% of candidates getting it right).

Discrimination. The discrimination index is satisfactorily high overall. The index reaches values of 0.63 and has a minimum of – 0.01. This is a satisfactory outcome, indicating that the Paper discriminated reasonably well. Those questions with a lower index sometimes have a high difficulty index, but not exclusively so, indicating that it is not always the case that 'hard' questions discriminate best between good and poor students.

Comments on selected questions

For the most part the questions were judged both by the examining team and by the schools to be good in that they were conceptual, well formulated and suited to the MCQ format. 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 when looking at a specific question. Thus comment will only be given on selected questions, i.e. those that illustrate a particular issue or where a problem was identified. Note that questions on which students performed well or which discriminated well will generally not be discussed, but can be identified from the analysis above. Detailed discussion is reserved for questions that students found difficult or where misconceptions are identified by the popularity of distracters. Thus most of the comments below identify conceptual difficulties that students have with certain physical situations, and hence should serve as feedback for teaching. Each of the comments below resulted from discussions in the Grade Award Meeting.

It should be noted that the use of boldface is intended to make it easier for the student to understand the question. It is, therefore, used sparingly. Candidates should appreciate that all words in all items are of importance.

Question 1

This question was in common with Standard Level (question 1) and was answered correctly by 24% of the candidates (as opposed to 23% at SL). Options A and B were intended to be approximate values for the diameter of a nucleus and for the diameter of an atom (if the unit is the metre). These Options proved to be very popular and were powerful distractors.

Question 5

This question was in common with Standard Level (question 4) and was answered correctly by 49% of the candidates (as opposed to 35% at SL).
It might have been better to state in the question that the resultant force is on the object. However, the most common incorrect response (Option D) indicates that candidates thought that a particle executing circular motion is in equilibrium! Clearly, this is an important teaching point.

Question 6

This question does not involve the calculation of a resultant vector and is, therefore, within the syllabus content. The discrimination index is high with a difficulty index of 56%, indicating that the item was successful.

Question 10

This question was removed from the Paper as a result of some confusion as to the sign of v_2. The stem of the question states that v_2 is a magnitude. It should, therefore, have been shown as $-v_2$ on the graph. Furthermore, the force is the net force on the ball, rather than the average force exerted by the plate on the ball.

Question 13

The discrimination index for this question was high. It was not intended that candidates should attempt to carry out any calculations, but to work intuitively. Clearly, the Key is not A or D. The Key cannot be B because the area of the two vertical 'arms' is greater than one half of the area of the horizontal section. The Key is C.

Question 22

There was some feeling amongst teachers that this was a difficult question for second language candidates. The difficulty index was 65% with a discrimination of 0.41. Consequently, the question proved to be successful from a statistical point of view. In practice, all candidates had to do in order to find the correct response was to look at what was stated to be moving in each Option.

Question 27

This question was in common with Standard Level (question 21) and was answered correctly by 68% of the candidates (as opposed to 48% at SL).
The most common incorrect response was Option A, illustrating the popular misconception that it is positive charge that can move on the rod or cloth. It is expected that candidates would realise that it is the electrons that are mobile.

Question 31

This question was in common with Standard Level (question 26) and was answered correctly by 66% of the candidates (as opposed to 51% at SL).
It may have been desirable to state in the stem of the question that the aluminium foil is held horizontally. However, judging by the response of candidates, there was no apparent problem as regards the orientation of the diagram.

Question 36

This question had a difficulty index of 43%. Statistics indicate that weaker candidates used guesswork as regards their responses. Candidates are expected to realise that the range of an ionising radiation is dependent on the initial energy of the radiation. Thus, with all particles having approximately the same range, they must have approximately the same initial energy.

Question 39

The subject of K-capture was merely to put the question into a context and any knowledge of this topic was unnecessary. Candidates were expected to understand nuclear equations and to know the notation for an electron. The question had a high difficulty index (74%) and did not appear to confuse more able candidates.

Areas where students had difficulties and areas where they were well prepared

It is difficult to generalise in a broad-based paper such as Paper1 over areas of difficulty or where students were well prepared. The comments on the individual questions and the percentages of student selections for each question should provide enough information about student difficulties and areas where they were well prepared. Some candidates struggled with the conceptual nature of these multiple-choice questions but it is encouraging to note from the statistics that many candidates did remarkably well.

Recommendations for the teaching of future candidates

The nature of the questions highlights the need to emphasize conceptual understanding of the basics. Qualitative reasoning about physical systems should be taught in addition to formula-based problem-solving.
Even though it may appear redundant to state this in this report, students need constant encouragement and reminders to read the questions carefully. Often, incorrect answers are given simply because the student has gone through the question too quickly and missed a crucial word that prevented him/her from getting the right answer. Examiners attempt to make questions as clear and as concise as possible. This implies that all wording is of importance.

Standard level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-20	21-26	27-33	34-37	38-50

General comments

The feedback from teachers was generally very positive. 90% thought that the paper was of the appropriate level of difficulty and the same percentage thought that the paper had a satisfactory or good syllabus coverage. All replies rated the clarity of wording and the presentation of the paper to be satisfactory or good. A clear majority rated the paper to be good in all aspects.

In general candidates appeared to allocate their time appropriately and there was no evidence that candidates were disadvantaged by lack of time. However, some candidates, as in previous years, did not pay heed to the space available for answering a particular sub-question or to the marks available and give needlessly lengthy answers.

Fewer candidates than in previous sessions made significant-digit errors and unit-omission errors.

The majority of candidates showed the steps in calculations, if at times somewhat messily, and so were able to take advantage of “error carried forward” marks. However it is worth mentioning that a significant number did not do so, or did so in a manner so obscure and “coded” that they could not be followed by the examiners or interpreted in a way which would favour the candidate in the marking.

Section A was compulsory while candidates had a choice of questions in Section B. The vast majority of candidates correctly followed the rubric and answered the required number of questions.

Areas of the program and examination which proved difficult for candidates

- Using graphs to obtain information
- Application of mechanics – as opposed to substituting into formulae
- The difference between gravitational and inertial mass
- Drawing “realistic” graphs
- Explanations of energy changes – as opposed to listing energy changes

- Potential divider circuits
- The difference between thermal energy and temperature
- The calculation of efficiency

The levels of knowledge, understanding and skills demonstrated

- Substitution into formulae in general
- Heat transfer mechanisms
- Good explanations of the cooling effect in evaporation
- Application of the power formula for electrical circuits
- Recall of the Rutherford experiment
- An understanding of how to handle error bars on graphs

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

Section A

Question 1 *Experimental investigation of Newton's second law.*

This question was well answered by most candidates. A few did have trouble realising that a proportional relation between two variables implies a straight line graph *through the origin*. Many candidates wrongly thought that the error bars in the graph were the systematic error. In the calculation of the mass of the trolley many used one data point to substitute into $F=ma$ and rearranged for m. Even though it cannot be assumed it is invariably the case that when information is to be extracted from a graph the gradient and the intercept will, in general, be required.

Question 2 *Atomic and nuclear structure.*

Part (a) was well answered with a few exceptions where candidates looked for explanations in other experiments such as Thomson's e/m experiment or the existence of atomic spectra. However, even in those cases where the Rutherford-Geiger-Marsden alpha particle scattering experiment was correctly identified and described, few candidates could correctly *explain* why the large angle scattering events were evidence for a nucleus.

Part (b) was well answered with most candidates realising the existence of the strong nuclear force (which interestingly most said was a force larger but not equal to the electrical force of repulsion).

Part (c) was not well answered. Many candidates used the wrong formula for the force and the arithmetic sometimes proved difficult. In (ii) it was sad to see many candidates using arguments such as the force was too small even when in (i) they had calculated a force of about 10^{26} N.

Question 3 *Sound waves.*

This question was well done by the great majority of candidates with the notable exception of part (a) where many thought that the wave was transverse. It has to be emphasised that a graph showing the variation with distance of the displacement, can be drawn for both longitudinal and transverse waves.

Section B

Question 1 *Electrical properties of two 12 V filament lamps.*

This was not a very popular question. Parts (a) and (b) of this question were very well done. In part (c) most candidates realised that the internal resistance of the battery or that of the wires or of the ammeter had something to do with the answer but few could a produce a clear argument. Many resorted to "if the voltage is reduced to zero the lamp won't work".

Part (d) involved the potential divider (potentiometer). It should be noted that the potential divider is on the syllabus and teachers are encouraged to use it both in practical laboratory work as well as in solving problems involving circuits.

In part (f) many candidates answered that the current in lamps A and B would be the same but then went on to contradict themselves in part (iii) by calculating the power in each lamp using a different current in each. Part (ii) of this question was not at all well done. Very few candidates realised that they had to use the graph to find two voltages adding up to 12 V.

Question 2 *Kinematics of an elevator.*

This was a very popular question on the paper and in general was satisfactorily done. In part (a) very few candidates were able to explain the difference between gravitational mass and inertial mass – many just explained the difference between mass and weight. Candidates did quite well in part (b). A few candidates used $P=Fv$ and then found the force from $F=ma$, without realising that for most of the motion the acceleration was zero. In part (c) quite a few candidates realised that a realistic graph meant (in this case) a smooth curve without corners at 0.5 s and 11.5 s but missed that point that the curve also had to be without corners at 0 s and 12 s as well.

In part (d) most candidates realised the relative sizes of the arrows representing the forces but were not always careful to show equal length arrows for the forces representing the (same) weight in the two diagrams.

Part (f) of this question proved difficult for the great majority of candidates. Many, incorrectly, thought that the problem was similar to a ball bouncing up and down under gravity with potential and kinetic energies transforming into each other. Most were content to answer the question with statements such as "the potential energy is increasing on the way up because the height of the elevator is increasing" and so on. One of the action verbs in the question was "explain" and therefore the answers to this question had to be a bit more detailed and sophisticated than the majority of the ones given. Only a disappointingly small number of candidates realised that electrical energy was involved here and even fewer realised that at the end of the up and down trip all the electrical energy delivered by the motor would have been converted into thermal energy and sound.

Question 3 *Thermal processes in a running person.*

This was a popular choice and there were some candidate who scored very highly indeed. Having said this the beginning was done very poorly with most candidates muddling the concepts. A good answer was very rare and many defined thermal energy as simply "heat". The mechanisms of heat transfer could often be named but candidates often missed out appropriate detail to gain full marks. In (d) (i) it was satisfying to see many complete answers with excellent explanations as to why cooling occurs in evaporation. Surface area was one obvious answer in (d) (iii) which was often missed. The role of temperature was seldom explained well and many confused the air temperature with the skin temperature.

Recommendations and guidance for the teaching of future candidates

The above comments on specific questions show the areas of the syllabus examined with which candidates often have difficulty.

In general when preparing candidates for the examination they should be encouraged to:

- Take note of marks allocations for whole questions and sub-sections of questions – they are indicators of the "weight of importance" the answer carries in the overall allocation of marks and give a guide to the length and/or complexity of the answer required.
- Read questions attentively and attempt to focus answers to what has been asked. This can be helped by frequent practice at past-paper questions, marked by teachers against the published markschemes.
- When a situation involves the application of several forces, a free-body diagram can be helpful. The drawing of, and concepts behind the free-body diagram need continued emphasis in the classroom. Care must be taken to show arrows whose lengths are proportional to the magnitude of the forces the arrows represent.
- In answering questions students should be encouraged to make remarks which indicate what they are doing or where they are going. Similar to REM comments in a computer program, these help the reader, at a later stage, follow the logic of the writer's thoughts and makes it simpler to award partial marks for partially successful attempts at the answer. Many students launch into a proof, for example, covering the page with formulae and equations and then fail to reach the answer. If they said where they were going at the beginning, it would be easier to follow their working and to give credit where it is due.
- There should be more practice in the classroom with graphs representing waves to make students understand that both transverse and longitudinal waves can be represented.
- The action verbs that appear in a question should be known to candidates and carefully considered when answering the question.
- When answering the examination, candidates should give careful consideration to the selection of a Section B question. They should be encouraged to read the questions carefully before making a selection.
- The use of past examination questions should be adopted early on in the course. Where possible whole questions or parts of questions should be used to reinforce learning and understanding when each syllabus topic or sub-topic is completed.

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-13	14-26	27-37	38-48	49-58	59-69	70-95

General comments

The feedback from teachers was generally very positive. Of the replies received, over 90% of teachers thought that the paper was of the appropriate level of difficulty. The syllabus coverage and the clarity of wording was rated as either satisfactory or good by the same high percentage of teachers. All replies felt the presentation of the paper to be satisfactory or good. A majority rated the paper to be good in clarity of wording and presentation.

Most candidates made significant digit errors or unit errors and so lost a mark.

The majority of candidates showed the steps in calculations. Explanation is important in that it enables candidates to take advantage of "error carried forward" marks where their work is not entirely correct.

Areas of the program and examination which proved difficult for candidates

- Application of mechanics – as opposed to substituting into formulae
- The difference between gravitational and inertial mass
- Explanations of energy changes – as opposed to listing energy changes
- Outlining the Bohr and Schrödinger models
- The details of beta decay
- Potential divider circuits
- The difference between thermal energy and temperature
- The calculation of efficiency

The levels of knowledge, understanding and skills demonstrated

- Substitution into formulae in general
- Recall of the Carnot cycle
- Work done by an engine from a p-V graph.
- Heat transfer mechanisms
- Application of the power formula for electrical circuits
- Recall of the Rutherford experiment
- An understanding of how to handle error bars on graphs

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

Section A

Question 1 *Experimental investigation of Newton's second law.*

This question was well answered by most candidates. A few did have trouble realising that a proportional relation between two variables implies a straight-line graph *through the origin*. Many candidates wrongly thought that the error bars in the graph were the systematic error. In the calculation of the mass of the trolley many used one data point to substitute into $F=ma$ and rearranged for m. Even though it cannot be assumed it is invariably the case that when information is to be extracted from a graph the gradient and the intercept will, in general, be required.

Question 2 *The kinematics of an elevator*

Very few candidates were able to explain the difference between gravitational mass and inertial mass – many just explained the difference between mass and weight. The free-body diagrams were often done well but many candidates' diagrams implied a changing value for the gravitational attraction on the elevator. The graph was often very muddled and it was rare to read a full explanation of the energy changes. The majority of the candidates simply listed the energy changes that were taking place. Many of these descriptions were also wrong with the descriptions often implying that the lift was in free fall!

Question 3 *Atomic structure and fundamental forces*

Part (a) was well answered with a few exceptions where candidates looked for explanations in other experiments such as Thomson's e/m experiment or the existence of atomic spectra. However, even in those cases where the Rutherford-Geiger-Marsden alpha particle scattering experiment was correctly identified and described, few candidates could correctly *explain* why the large angle scattering events were evidence for a nucleus.

Part (b) was well answered with most candidates realising the existence of the strong nuclear force (which interestingly most said was a force larger but not equal to the electrical force of repulsion).

Part (c) was not well answered. Many candidates used the wrong formula for the force and the arithmetic sometimes proved difficult. A surprisingly large number of candidates used the Boltzmann constant in place of the coulomb constant in the equation for the force between two charges. Many answered part (d) well but a significant number only used the mass of the electrons to calculate the force. In part (e) it was sad to see many candidates using arguments such as the force was too small even when in (c) they had calculated a force of about 10^{26} N.

Section B

The most popular option question in this section was B4 and the least popular was B1.

Question 1 *Atomic and nuclear aspects of helium isotopes*

Candidates tended to lose marks through lack of detail rather than understanding in the first sections of this question. A pleasing number could correctly identify the energy levels involved but a significant number got the jump the wrong way round. The outline of the different atomic models was done poorly with many candidates explaining why energy levels explained the spectrum of atomic hydrogen rather than outlining the models. The nuclear aspects were generally done well though few were able to correctly apply any knowledge of antineutrinos or quarks to beta decay.

Question 2

Part 1 *The forces on a wheelbarrow*

This question was done reasonably well even though some candidates clearly misunderstood the physics contained in the question. The wording of the question did not make it absolutely clear that candidates were expected to consider the support legs of the barrow to be just lifted off the ground for part (a)(ii) or that the wheel barrow was at an angle to the horizontal while being pushed in part (b). This decision was taken to improve the readability of the question and no candidate would have been disadvantaged if they made different assumptions. Having said this, it was common to see answers that never attempted to use the concept of moments in the first section and failed to understand the need to resolve in the second part of the question. Finally, many wrongly attempted to use a coefficient of friction calculation to calculate the frictional force rather than using Newton's laws.

Part 2 *Electrical properties of two 12 V filament lamps*

Candidates tended to do poorly on this question. Few were able to understand the limits to the experimental technique described and the vast majority had clearly never come across the potentiometer as a three terminal device. This is surprising as it is good procedure to use such a circuit in practical situations. It should be noted that the potential divider is on the syllabus and teachers are encouraged to use it both in practical laboratory work as well as in solving problems involving circuits. Having said this, many were able to calculate which bulb had the greater power dissipation at 12 V. As might have been expected few were able to correctly use the information provided in the graph to identify the total current drawn when the two bulbs were placed in series. Some candidates calculated the resistance at 12 V and then assumed that it remained constant. It was, however, pleasing to see that a significant number could use the graph properly.

Question 3

Part 1 *The physics of a lightning strike*

Marks tended to be lost for lack of detail in the beginning sections of this question. Often the weaker candidates tended to repeat the words used in the question – e.g. "When charges are separated" is not a sufficient explanation of the term *charge separation*. The calculations, however, tended to be done well and it was pleasing to see that a majority of candidates were able to correctly substitute values into an unfamiliar equation. Almost no candidate realised that the average potential difference was more appropriate to the calculation of the energy of the lightning strike.

Part 2 *Sound waves*

Candidates tended either to do well on all aspects of this section or to score very poorly indeed. Typically a candidate who was struggling with the question resorted to substitution into an inappropriate formula. The Doppler equation was popular in this context. Many realised that the final situation was an example of beats, but a smaller number were able to deduce the correct values for the frequencies

Question 4

Part 1 *Thermal processes in a running person*

There were some candidate who scored very highly indeed on this question. Having said this, the beginning was done very poorly with most candidates muddling the concepts. A good answer was very rare and many defined thermal energy as simply "heat". The mechanisms of heat transfer could often be named but candidates often missed out appropriate detail to gain full marks. Surface area was one obvious answer in (d) (ii) which was often missed. The role of temperature was seldom explained well and many confused the air temperature with the skin temperature.

Part 2 *The thermodynamics of a heat engine*

Some were able to gain full marks on this question but it was common to see the efficiency calculation completely muddled. It was very usual to see candidates dividing the work done by the thermal energy ejected in an attempt to get the efficiency. In the rest of the question, marks were lost as a result of lack of precision and detail in the descriptions of the Carnot cycle.

Recommendations and guidance for the teaching of future candidates

The above comments on specific questions show the areas of the syllabus examined with which candidates often have difficulty.

In general when preparing candidates for the examination they should be encouraged to:

- Take note of marks allocations for whole questions and sub-sections of questions – they are indicators of the "weight of importance" the answer carries in the overall allocation of marks and give a guide to the length and/or complexity of the answer required.
- Read questions attentively and attempt to focus answers to what has been asked. This can be helped by frequent practice at past-paper questions, marked by teachers against the published markschemes.
- When a situation involves the application of several forces, a free-body diagram can be helpful. The drawing of, and concepts behind, the free-body diagram need continued emphasis in the classroom. Care must be taken to show arrows whose lengths are proportional to the magnitude of the forces the arrows represent.
- In answering questions students should be encouraged to make remarks which indicate what they are doing or where they are going. Similar to REM comments in a computer program, these help the reader, at a later stage, follow the logic of the writer's thoughts and makes it simpler to award partial marks for partially successful attempts at the answer. Many students launch into a proof, for example, covering the page with formulae and equations and then fail to reach the answer. If they said where they were going at the beginning, it would be easier to follow their working and to give credit where it is due.
- The action verbs that appear in a question should be known to candidates and carefully considered when answering the question.
- When answering the examination, candidates should give careful consideration to the selection of the Section B questions. They should be encouraged to read the questions carefully before making a selection.

- The use of past examination questions should be adopted early on in the course. Where possible whole questions or parts of questions should be used to reinforce learning and understanding when each syllabus topic or sub-topic is completed.

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-15	16-19	20-24	25-28	29-40

General comments

The number of comments received from teachers was limited but greatly appreciated by the examining team. The majority of those that did comment felt that the paper was of a similar standard in comparison to last year's paper but some felt it was a little more difficult. The vast majority felt that the paper was of an appropriate level of difficulty, and rated the clarity of wording and the syllabus coverage either 'satisfactory' or 'good'. All rated the presentation of the paper as satisfactory or good.

Option A and H were, as in previous years, the most popular Options. Option F was also popular and Options D least popular. Possibly as a result of a complete re-write of Option E, it would seem that more candidates attempted this Option than previously.

The areas of the programme which proved difficult for candidates

As in previous years, there were not many attempts at Option B (Nuclear Physics), Option C (Energy extension) and Option D (Medical Physics). This may suggest that these Options are perceived by teachers to contain subject matter that is difficult to teach. In a November session where the number of candidates globally is relatively small, it is difficult to generalise about why certain Options are not tackled.

Other areas of difficulty identified by the examining team include:

- Algebraic manipulation
- Forces in equilibrium
- Gravitation
- Electron diffraction
- Principles of scaling.
- Verification of Coulomb's law
- Handling ratios (Astrophysics)
- Time dilation and length contraction
- Ray diagrams

The levels of knowledge, understanding and skill demonstrated

Most candidates coped well with standard definitions, with substituting numerical values into standard formulas and with graph plotting. The level of knowledge and understanding varied, just as one would expect across the entry with some candidates showing an excellent grasp of the concepts tested in this examination. At the other end of the scale some candidates exhibited little or no understanding of the concepts addressed by the questions. In questions that asked for explanations, outlines, suggestions or descriptions, candidates often resorted in their answers to anecdote rather than to principles of physics. The levels of knowledge and understanding are treated in more detail in the following section.

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

It should be borne in mind that there were a pleasing number of candidates who showed a firm grasp and understanding of the topics addressed by the different option questions. The comments below refer to the main areas of weakness shown by candidates who fail to achieve this level of performance.

A Mechanics Extension

Question 1 *Projectile motion*

Most candidates drew correct arrows to show the directions of the acceleration and velocity of the stone. The kinetic energy of the stone was often correctly calculated but a significant number of candidates thought that the KE of the stone at point Q was zero.
Although the introduction to the question specifically states that it is about using an energy argument to find the final speed, many candidates incorrectly used an equation of uniform motion to calculate the final speed.

Question 2 *Static equilibrium*

Very few candidates appreciated that when three forces are in equilibrium, their line of action will pass through the same point.
A significant number of candidates used $T\sin\theta$ to find the horizontal component of the force

Question 3 *Satellite*

Many candidates appreciated that only a single force acts on the satellite and most were able to deduce the expression of the velocity. However, attempts at deducing the expression for T^2 were often confused. There would seem to be an optimism amongst some candidates, that if they write down enough algebraic expressions at random, then the desired result will eventually appear. This is true not only here but also elsewhere on the paper where deduction is required. Many candidates did not use the information given to show that the orbital period is about 24 hours but instead used a value of G to find the mass of the Earth and then the period.

B Atomic and nuclear physics extension

Question 1 *Wave nature of electrons*

The de Broglie hypothesis was usually understood and quite a few candidates calculated the wavelength correctly. However, there was a lot of confusion here with the Planck formula for photons.
The concept of electron diffraction and its relationship to the verification of the de Broglie hypothesis was poorly understood.

Question 2 *Atomic Spectra and energy levels*

This was probably the best answered question in this Option although some candidates drew the arrows on the energy level diagram in the opposite direction.

Question 3 *Radioactive decay.*

Many candidates recognised the decay as an example of positive beta decay but the calculation of the decay constant defeated many.

C Energy extension

Question 1 *Solar panels and wind turbine*

This was not a popular Option but this question was done better than question 2. However, many candidates seem to have little idea of size with many thinking that an area of a correctly calculated value of 26 m^2 would fit comfortably on the roof of the average house.
The wind turbine calculations were often done well.

Question 2 *The Carnot cycle*

There were some wild attempts at this question with a lot of candidates having only the vaguest idea of the shape of the Carnot cycle. This in turn led to much incorrect labelling of the diagram. The efficiency of the engine was usually calculated correctly but the calculation of the thermal power defeated many candidates.

D Medical Physics

Question 1 *Scaling*

Many candidates did not analyse the question as regards the dependence on L of power loss and of mass. Consequently, they were unable to obtain the dependence on L of power loss per unit mass. There was much guesswork as to the relationship, often indicating a lack of understanding of the situation. Those candidates who had an appreciation of the situation were usually able to give a sensible assumption in making the estimate.
There was a clear distinction between candidates who had studied the subject and those had no appreciation of the physics involved in explaining the range of animal sizes found in nature.

Question 2 *Comparison of hearing abilities*

There were very few correct answers to determining the ratio. Many answers did not include the relationship between intensity and amplitude. Of those candidates who did give the expression, the majority could not negotiate the subsequent mathematics.
The expression for loss / dB was applied correctly in many scripts.
Candidates should realise that, where the command in a question is ‘state and explain’, then some words of explanation are necessary in order to score full credit. Far too frequently, the explanation for the frequency to which Carmen was most sensitive, was lacking.
With few exceptions, the candidates who had calculated a value for the loss in (b) correctly labelled the graph. Points at 60 dB and 70 dB were both accepted.

Question 3 X-rays

There were some carefully drawn sketches. However, many candidates lost marks through carelessness. Candidates should be advised that, where a graph is to be sketched, the important features of the graph should be made clear. In this case, a free-hand curve was acceptable but the exponential nature of the decay should be clear.
Answers indicated a large measure of guesswork in explaining which photon energy would be the most suitable. It was not appreciated that the X-rays should be able to penetrate the muscle but, at the same time, in order to have good contrast penetration of the bone must be much less. 30 keV X-rays would be more appropriate

E Historical Physics

Question 1 *Newton*

There were surprisingly few correct answers in estimating the acceleration of the Moon.
Many substituted directly the acceleration for *F*. It was expected that centripetal acceleration would be considered in the alternative method of calculating the acceleration. In general, this was the case, but there were numerous expressions given without any explanation as to how they were derived.
It was unfortunate that very few candidates derived correctly the accelerations from the two methods. However, many did realise that the two values should be approximately equal. Consequently, statements to this effect were made, even when the values differed by a factor of 10^{10}. Candidates should be advised that the command word *explain* implies that more than a statement to the effect that the two are equal is required. The concept of *universal* was not appreciated by weaker candidates who confused 'universal' with 'world wide'.

Question 2 *Coulombs Law*

Candidates seemed to appreciate the concept of charge sharing and consequently, gave a correct expression for the force on either sphere. In subsequent parts, It was unfortunate that many candidates attempted an answer in terms of a full expression of Coulomb's law, rather than in terms of *F* – the force above. Very rarely was a reference made to the concept of a point charge in stating why the separation of the spheres is much greater than their diameter. Despite some good answers in (a) and (b), many candidates were unable to express the concept of charge sharing and the effect on the force between the spheres. In general, descriptions of Coulomb's measurement of the force were poor. Usually, a suspension was shown, but fixed charged spheres were frequently omitted. Very rarely was there any mention of the role of the restoring torque provided by the suspension. Candidates should be encouraged to draw sketch diagrams, where appropriate. Many answers did not include a sketch, despite the provision of a space in the question book.

F Astrophysics

Question 1 *Planets in the Solar system.*

With few exceptions, the orders were correct and candidates were given full credit.

Question 2 *Barnard's star*

In general, in explaining parallax angle and its measurement a diagram was drawn. However, many defined the parsec, rather than the parallax angle. Those candidates who did define parallax angle frequently failed to appreciate that observations of the star at a six-monthly interval would give twice the parallax angle. The calculation of the distance of the star from Earth was completed successfully by the great majority of candidates but few defined apparent brightness correctly. Many stated that it is the brightness observed from Earth or referred to energy received on Earth, rather than power per unit area. The determination of the ratio proved difficult. The majority of answers included a correct expression. However, there were few correct responses. Many candidates found difficulty with either the substitution or the subsequent arithmetic. There were some very good responses to why the star cannot be either a white dwarf or red giant.

Option G Special and General Relativity

At Higher Level this is always a popular choice, and its popularity at Standard Level is growing. This session it was quite a popular option at both levels.

Question 1 *The relativistic motion of muons*

Most candidates did appreciate that in defining proper length, the observer must be at rest with respect to the object. However, many answers to proper time involved being 'at rest to measure a time' rather than a time interval in a reference frame where the two events defining the interval occur at the same place. Many candidates thought that an inertial observer must be at rest rather than in a reference frame moving at constant velocity.
In general, the half-life was calculated successfully and most candidates gave a correct expression for the half-life. However, there were many different arithmetical errors, particularly when calculating γ. In a significant number of answers, the length was calculated to be greater then 1370 m. Answers to explaining time dilation and length contraction were disappointing. It was apparent that the majority of candidates did not understand the concepts involved and made disjointed and frequently inaccurate statements ignoring any idea of relative motion. The more able candidates gave statements as to the meanings but were unable to elaborate successfully on their statements. There were some good answers to explaining why a muon can never attain the speed of light involving the ratio v/c approaching zero and its effect on mass. The most serious problem was in reading the values from the axes. However, the majority of answers were within acceptable limits. In general, those candidates who gave an answer in (e)(ii) also quoted a correct answer to the total energy the muon. However, many failed to complete their work with a correct expression for the total energy and hence did not allow for rest mass energy. It is appreciated that the rest mass of the muon is actually 106 MeV but this did not affect the question in any way!

Option H Optics

Question 1 *Optical dispersion*

With few exceptions, the graph was read correctly. However, the majority gave the answer for the refractive index to two or three significant digits. Candidates were encouraged to sketch a diagram and indeed, more able candidates benefited by this. Weaker candidates frequently showed dispersion occurring as the light left a prism, not as it enters and leaves.

Question 2 *Real and apparent depth*

It was surprising to note the large proportion of ray diagrams that were unrecognisable. Candidates should be encouraged to practice the drawing of ray diagrams. In general, a correct statement was given as to the nature of the image with adequate explanation. The calculation was completed successfully in the majority of cases. The most common error was to give the position relative to the upper surface, rather than the bottom of the pool.

Question 3 *The simple magnifying glass.*

There were many good diagrams, with the rays drawn with rulers. However, there was a significant number of attempts to produce a real image to the right of the lens. For those candidates who had drawn correct construction rays, the positioning of the image presented no problem and with few exceptions, the eye was drawn on the right-hand side of the diagram. Candidates should learn to distinguish between *near point* and *least distance of distinct vision*. A significant number of answers did not include the fact that the eye can focus on an object at this point. With few exceptions, the lens formula was quoted. Most did calculate correctly the image distance. However, the great majority assumed that the image would be real. There were many correct answers to the idea of the far point. However, a common error was to think that the object should be placed at infinity.

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

This examination, as in previous years, it was particularly evident that many candidates are able to make reasonable attempts at mathematical calculations but often failed to be able to explain the ideas and the concepts in reasonable detail. It should be stressed again that candidates could be encouraged to practise summarizing Physics explanations by identifying the key or essential elements in a logical and organised manner. Many candidates obviously have had the opportunity to practice working through past IB papers but fewer seemed to have had practice at reviewing their answers in the light of past mark schemes. A particular weakness is in the length of the answers provided and candidates should be encouraged to write succinctly. Extra correct material will never be penalised, but it is a general observation that long answers often end up containing some contradictions or misconceptions and not scoring as highly a shorter and more concise descriptions. Equally important but often forgotten by candidates under the pressure of an examination is that answers should provide something more than just a rearrangement of the information provided in the question.

Suggestions identified by the examining team include:

- Practice at the manipulation and interpretation of unfamiliar data – particularly if presented in graphical form.
- Students could gain confidence and fluency by going through the syllabus in detail to check their understanding – all too often a good paper contains a poorly answered section.
- More practice at descriptive answers. Calculations are often done well as compared with descriptions that tend to be muddled or confused.

In general

- Options should not be left to the end of a course.
- Teachers should use every opportunity for integrating the chosen options into the rest of the course. This is particularly applicable to Historical Physics.
- Options need to be taught – or at least actively monitored. There is evidence that some schools are leaving the candidates to study one option in their own time.
- Handwriting must be legible.
- The order for mathematical working should be clear to the examiner. Some candidates prefer to work in columns, other across the page. Both are acceptable, but jottings all over the page are unacceptable.
- Logical connections between mathematical statements need to be made. Candidates should, as a matter of course use: $\Leftrightarrow$; so; (given); therefore …etc.
- It should be clear to the examiner where numbers come from. It is not sufficient to copy a number from a calculator without indicating on the script the numbers that were fed into the calculator
- Candidates need practice in manipulating proportionality, without working out the constant of proportionality.
- 'Show that…' questions need to be tightly and rigorously justified at each step. Trial and error solutions are not acceptable.
- Algebraic terms introduced by the student need to be defined.

- Candidates should be tested frequently in giving short explanations. Ideally these should be marked by the students according to a strict marking scheme. Such activities make useful starters to a lesson and need take no longer than five minutes.
- Candidates should avoid adding more to an answer than is required by the question. Superfluous inaccuracies could result in marks being lost.
- The number of marks for each question is an indication of the number of points the students need to make. Two marks will not be awarded for one statement.
- Questions that invite the candidates to 'Explain with reference to ……' are looking for a very specific response. A general textbook explanation is not sufficient.

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-8	9-17	18-22	23-28	29-35	36-41	42-60

General comments

The number of comments received from teachers was limited but greatly appreciated by the examining team. The majority of those that did comment felt that the paper was of a similar standard in comparison to last year's paper but some felt it was a little more difficult. The vast majority felt that the paper was of an appropriate level of difficulty, and rated the clarity of wording and the syllabus coverage either 'satisfactory' or 'good'. All rated the presentation of the paper as satisfactory or good.

The areas of the programme which proved difficult for candidates

As in previous years, there were few attempts at Option D (Medical Physics) and Option E (Historical Physics) although the questions were straightforward. This may suggest that these Options are perceived as difficult to teach or that the questions are not very accessible. In a November session where the number of candidates globally is relatively small, it is difficult to generalise about why certain Options are not tackled.

Other areas of difficulty identified by the examining team include:

- Algebraic manipulation
- Forces in equilibrium
- Gravitation
- Electron diffraction
- Principles of scaling.
- Verification of Coulomb's law
- Handling ratios (Astrophysics)
- Time dilation and length contraction
- Equivalence Principle
- Ray diagrams
- Thin film interference
- Rayleigh criterion

The levels of knowledge, understanding and skill demonstrated

Most candidates coped well with standard definitions, with substituting numerical values into standard formula and with graph plotting. The level of knowledge and understanding varied, just as one would expect across the entry with some candidates showing an excellent grasp of the concepts tested in this examination. At the other end of the scale some candidates exhibited little or no understanding of the concepts addressed by the questions. In questions that asked for explanations, outlines, suggestions or descriptions, candidates often resorted in their answers to anecdote rather than to principle of physics. The levels of knowledge and understanding are treated in more detail in the following section.

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

It should be borne in mind that there were a pleasing number of candidates who showed a firm grasp and understanding of the topics addressed by the different option questions. The comments below refer to the main areas of weakness shown by candidates who fail to achieve this level of performance.

D Medical Physics

Question 1 *Scaling*

Many candidates did not analyse the question as regards the dependence on L of power loss and of mass. Consequently, they were unable to obtain the dependence on L of power loss per unit mass. There was much guesswork as to the relationship, often indicating a lack of understanding of the situation. Those candidates who had an appreciation of the situation were usually able to give a sensible assumption in making the estimate. There was a clear distinction between candidates who had studied the subject and those had no appreciation of the physics involved in explaining the range of animal sizes found in nature.

Question 2 *Comparison of hearing abilities*

There were very few correct answers to determining the ratio. Many answers did not include the relationship between intensity and amplitude. Of those candidates who did give the expression, the majority could not negotiate the subsequent mathematics. The expression for loss / dB was applied correctly in many scripts. Candidates should realise that, where the command in a question is 'state and explain', then some words of explanation are necessary in order to score full credit. Far too often, the explanation for the frequency to which Carmen was most sensitive, was lacking. With few exceptions, the candidates who had calculated a value for the loss in (b) correctly labelled the graph. Points at 60 dB and 70 dB were both accepted.

Question 3 X-rays

There were some carefully drawn sketches. However, many candidates lost marks through carelessness. Candidates should be advised that, where a graph is to be sketched, the important features of the graph should be made clear. In this case, a free-hand curve was acceptable but the exponential nature of the decay should be clear.
Answers indicated a large measure of guesswork in explaining which photon energy would be the most suitable. It was not appreciated that the X-rays should be able to penetrate the muscle but, at the same time, in order to have good contrast penetration of the bone must be much less. 30 keV X-rays would be more appropriate

Question 4 *Forces on the forearm*

Generally, this calculation was completed successfully. However, there was a marked tendency for candidates not to explain their working. This can have serious consequences where the work is not completed successfully since marks cannot be awarded for intermediate steps in the working.
There was a number of good answers to explaining the advantages of the design of the forearm. However, the majority of the candidates did not appreciate the situation. The concept of the mechanical disadvantage giving rise to comparatively large movements of the load was not understood by many, despite this being a fundamental aspect of the design.

Question 5 *Effectiveness of radiation*

Quality factor was very poorly understood. The fact that it is the means by which doses of different radiations may be *compared* was not appreciated.
There were some good answers to determining the exposure time. Others achieved the correct answer but the working was very difficult to follow. This calculation is another example of where clear explanation is advantageous to the candidate.

E Historical Physics

Question 1 *Newton*

There were surprisingly few correct answers in estimating the acceleration of the Moon.
Many substituted directly the acceleration for *F*. It was expected that centripetal acceleration would be considered in the alternative method of calculating the acceleration. In general, this was the case, but there were numerous expressions given without any explanation as to how they were derived. It was unfortunate that very few candidates derived correctly the accelerations from the two methods. However, many did realise that the two values should be approximately equal. Consequently, statements to this effect were made, even when the values differed by a factor of 10^{10}. Candidates should be advised that the command word *explain* implies that more than a statement to the effect that the two are equal is required.
The concept of *universal* was not appreciated by weaker candidates who confused 'universal' with 'world wide'.

Question 2 *Coulomb's Law*

Candidates seemed to appreciate the concept of charge sharing and consequently, gave a correct expression for the force on either sphere. In subsequent parts, It was unfortunate that many candidates attempted an answer in terms of a full expression of Coulomb's law, rather than in terms of *F* – the force above. Very rarely was a reference made to the concept of a point charge in sating why the separation of the spheres is much greater than their diameter.
Despite some good answers in (a) and (b) ,many candidates were unable to express the concept of charge sharing and the effect on the force between the spheres. In general, descriptions of Coulomb's measurement of the force were poor. Usually, a suspension was shown, but fixed charged spheres were frequently omitted. Very rarely was there any mention of the role of the restoring torque provided by the suspension. Candidates should be encouraged to draw sketch diagrams, where appropriate. Many answers did not include a sketch, despite the provision of a space in the question book.

Question 3 *The Bohr model and uncertainty*

Generally, candidates did little more than state that the electrons are in fixed orbits. Angular momentum and the emission of energy only on de-excitation were rarely included. With few exceptions, all three answers to the first calculations were correct. However, most candidates were unable to give an expression for the Uncertainty principle. Very rarely did a candidate appreciate that, based on the Uncertainty principle, the concept of clearly defined orbits is inappropriate.

F Astrophysics

Question 1 *Planets in the Solar system.*

With few exceptions, the orders were correct and candidates were given full credit.

Question 2 *Barnard's star*

In general, in explaining parallax angle and its measurement a diagram was drawn. However, many defined the parsec, rather than the parallax angle. Those candidates who did define parallax angle frequently failed to appreciate that observations of the star at a six-monthly interval would give twice the parallax angle. The calculation of the distance of the star from Earth was completed successfully by the great majority of candidates but few defined apparent brightness correctly. Many stated that it is the brightness observed from Earth or referred to energy received on Earth, rather than power per unit area. The determination of the ratio proved difficult. The majority of answers included a correct expression. However, there were few correct responses. Many candidates found difficulty with either the substitution or the subsequent arithmetic. There were some very good responses to why the star cannot be either a white dwarf or red giant.

Question 3 *Evolution of stars*

With few exceptions candidates appreciated the process that provides energy for the main sequence stars. However, with weaker candidates, there was some confusion between fission and fusion. Most realised that high temperatures are required for fusion. Others also included high pressure. Most candidates realised that the hydrogen would be 'used up'. In general, answers to the evolution of stars of different masses, were disappointing. Candidates tended to give just a few isolated facts that were not in sequence. Furthermore, very few discussed the role of the Chandrasekhar limit..

G Special and General Relativity

At Higher Level this is always a popular choice, and its popularity at Standard Level is growing. This session it was quite a popular option at both levels.

Question 1 *The relativistic motion of muons*

Most candidates did appreciate that in defining proper length, the observer must be at rest with respect to the object. However, many answers to proper time involved being 'at rest to measure a time' rather than a time interval in a reference frame where the two events defining the interval occur at the same place. Many candidates thought that an inertial observer must be at rest rather than in a reference frame moving at constant velocity. In general, the half-life was calculated successfully and most candidates gave a correct expression for the half-life. However, there were many different arithmetical errors, particularly when calculating γ. In a significant number of answers, the length was calculated to be greater then 1370 m. Answers to explaining time dilation and length contraction were disappointing. It was apparent that the majority of candidates did not understand the concepts involved and made disjointed and frequently inaccurate statements ignoring any idea of relative motion. The more able candidates gave statements as to the meanings but were unable to elaborate successfully on their statements. There were some good answers to explaining why a muon can never attain the speed of light involving the ratio v/c approaching zero and its effect on mass. The most serious problem was in reading the values from the axes. However, the majority of answers were within acceptable limits. In general, those candidates who gave an answer in (e)(ii) also quoted a correct answer to the total energy the muon. However, many failed to complete their work with a correct expression for the total energy and hence did not allow for rest mass energy. It is appreciated that the rest mass of the muon is actually 106 MeV but this did not affect the question in any way!

Question 2 *Equivalence principle*

The number of correct answers for the paths was surprisingly low. Many drew either two straight lines or two curves. Consequently, explanations were rarely adequate and many candidates scored little or no credit.
Very few answers to the explanation included any form of statement of the equivalence principle. Candidates seemed to be very confused and were unable to give any relevant information.

Question 3 *Speed of a particle*

The calculation was completed successfully by many candidates. It appeared as if they were well-practiced in answering this type of relatively straight-forward calculation.

H Optics

Question 1 *Optical dispersion*

With few exceptions, the graph was read correctly. However, the majority gave the answer for the refractive index to two or three significant digits. Candidates were encouraged to sketch a diagram and indeed, more able candidates benefited by this. Weaker candidates frequently showed dispersion occurring as the light left a prism, not as it enters and leaves.

Question 2 *Real and apparent depth*

It was surprising to note the large proportion of ray diagrams that were unrecognisable. Candidates should be encouraged to practice the drawing of ray diagrams.
In general, a correct statement was given as to the nature of the image with adequate explanation. The calculation was completed successfully in the majority of cases. The most common error was to give the position relative to the upper surface, rather than the bottom of the pool.

Question 3 *The simple magnifying glass.*

There were many good diagrams, with the rays drawn with rulers. However, there was a significant number of attempts to produce a real image to the right of the lens. For those candidates who had drawn correct construction rays, the positioning of the image presented no problem and with few exceptions, the eye was drawn on the right-hand side of the diagram. Candidates should learn to distinguish between *near point* and *least distance of distinct vision*. A significant number of answers did not include the fact that the eye can focus on an object at this point. With few exceptions, the lens formula was quoted. Most did calculate correctly the image distance. However, the great majority assumed that the image would be real. There were many correct answers to the idea of the far point. However, a common error was to think that the object should be placed at infinity.

Question 4 *Thin films*

The most common answers to the origin of thin film fringes were refraction and diffraction. Only a minority gave the correct answer of interference.
n was frequently referred to as refractive index without any mention that it applied to the oil. The fact that the wavelength depends on *n* was mentioned in only a very small number of scripts. The simple calculation caused very few problems. However, very few candidates appreciated that there would be a phase change on reflection from the lower boundary and consequently very few marks were scored in this section.

Question 5 *Rayleigh criterion*

Most candidates identified diffraction as the limiting factor but a significant minority chose refraction. There was a number of very good answers to the explanation of the Rayleigh criterion. However, the majority of candidates drew sketches that were of no value. A carefully drawn would have been an adequate substitute for a written explanation of the criterion.

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

In this examination, as in previous years, it was particularly evident that many candidates are able to make reasonable attempts at mathematical calculations but often failed to be able to explain the ideas and the concepts in reasonable detail. It should be stressed again that candidates could be encouraged to practise summarizing Physics explanations by identifying the key or essential elements in a logical and organised manner. Many candidates obviously have had the opportunity to practice working through past IB papers but fewer seemed to have had practice at reviewing their answers in the light of past mark schemes. A particular weakness is in the length of the answers provided and candidates should be encouraged to write succinctly. Extra correct material will never be penalised, but it is a general observation that long answers often end up containing some contradictions or misconceptions and not scoring as highly a shorter and more concise descriptions. Equally important but often forgotten by candidates under the pressure of an examination is that answers should provide something more than just a rearrangement of the information provided in the question.

Suggestions identified by the examining team include:

- Practice at the manipulation and interpretation of unfamiliar data – particularly if presented in graphical form.
- Students could gain confidence and fluency by going through the syllabus in detail to check their understanding – all too often a good paper contains a poorly answered section.
- More practice at descriptive answers. Calculations are often done well as compared with descriptions that tend to be muddled or confused

In general

- Options should not be left to the end of a course.
- Teachers should use every opportunity for integrating the chosen options into the rest of the course. This is particularly applicable to Historical Physics.
- Options need to be taught – or at least actively monitored. There is evidence that some schools are leaving the candidates to study one option in their own time.
- Handwriting must be legible.

- The order for mathematical working should be clear to the examiner. Some candidates prefer to work in columns, other across the page. Both are acceptable, but jottings all over the page are unacceptable.
- Logical connections between mathematical statements need to be made. Candidates should, as a matter of course use: ⇔; so; (given); therefore …etc.
- It should be clear to the examiner where numbers come from. It is not sufficient to copy a number from a calculator without indicating on the script the numbers that were fed into the calculator.
- Candidates need practice in manipulating proportionality, without working out the constant of proportionality.
- 'Show that…' questions need to be tightly and rigorously justified at each step. Trial and error solutions are not acceptable.
- Algebraic terms introduced by the student need to be defined.
- Candidates should be tested frequently in giving short explanations. Ideally these should be marked by the students according to a strict marking scheme. Such activities make useful starters to a lesson and need take no longer than five minutes.
- Candidates should avoid adding more to an answer than is required by the question. Superfluous inaccuracies could result in marks being lost.
- The number of marks for each question is an indication of the number of points the students need to make. Two marks will not be awarded for one statement.
- Questions that invite the candidates to 'Explain with reference to ……' are looking for a very specific response. A general textbook explanation is not sufficient.

Internal Assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-15	16-21	22-27	28-31	32-37	38-48

The range and suitability of the work submitted

There was a wide range of practical investigations, from innovative work, through traditional labs to simplistic fill-in–the blank exercises. On average, the majority of work was good high school level physics. Many schools covered the syllabus topics including options and group 4 projects. Many schools covered the required time, although it was not uncommon to find 2 or 3 hours listed for a simple lab. Most schools sent in the required written/verbal instructions.

Candidate performance against each criterion

Many schools are assigning relevant and interesting planning (a) and (b) exercises. The influence of the OCC was evident. However, a number of students were penalized because the teacher assigned inappropriate investigations, such as determining the specific heat capacity of an unknown substance, or to confirm Newton's second law. In physics, data collection always requires acknowledgement of uncertainties. Some schools are still ignoring this. Under data processing and presentation, teachers often told the student what to graph and so the student could not earn a complete. Although the aspects are spelled out for the conclusion and evaluation criterion , it appears that many teachers and students have not read them. This should be one of the easier criteria to succeed in but it often proved the most difficult.

Recommendations for the teaching of future candidates

Teachers need a clear idea of what criterion or criteria (if any) are to be assessed before they assign an investigation, and they should make this clear to the students. Students should have copies of the IA criteria when writing up their work. Teachers should not assign well-defined topics for planning investigations. If the student is asked to determine the value of some physical quantity then you know this is an inappropriate planning investigation. See the OCC for details and examples here. Teachers should be aware that when using the group 4 project for assessment and students are working in groups, the individual work of each student must be identified. Raw data should include units and uncertainties. Students must design their own data tabulation. Under processing and presentation, students must select quantities to represent and the way the graph is designed.
Careful attention needs to be made to the details of each aspect in the conclusion and evaluation criterion. Often teachers awarded a “3” when no weakness or improvements were mentioned. Teachers should send in only the material that is to be moderated, and this should be clearly indicated. Finally, lab time is class time (and not out of class write-up time).

Further comments

Although the majority of schools followed the instruction on submitting the required material and completing the 4/PSOW forms, a number of school still made mistakes and caused problems for moderation. Overall, the majority of school followed the requirements correctly and they marked IA in a reasonable way. Many schools have detailed IA assessment sheets, and this really helps the student and the moderator.

