PHYSICS (IBNA/IBLA)

To improve the security of IB examinations, a selection of examination papers now have regional variants, including physics HL and SL papers 1, 2 and 3. The following report is for *physics* taken by candidates in the IB regions of North America and Latin America.

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-28	29-40	41-52	53-62	63-73	74-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-28	29-39	40-50	51-60	61-71	72-100

Thanks are extended to those schools and teachers who have commented on particular questions on the G2 feedback forms. Teachers are strongly encouraged to send in G2 comments on all components of the external examination, Papers 1, 2 and 3 SL and/or HL. These may be sent either by hard copy, via IBNET or the OCC. These comments provide valuable information to the Grade Award team in respect of determining grade boundaries.

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

It would seem that more Schools than last year are producing imaginative, well-balanced programmes that give good syllabus coverage both of the Core and the Options and which also expose the candidates to a wide range of experimental techniques. These schools demonstrate that good experiments can be designed using simple equipment. However, some schools' programmes continue to be dominated by experiments in mechanics at the expense of the other parts of the syllabus.

In some cases very little knowledge was displayed of the various measurement techniques available in experimental work or of the different analytical techniques available for dealing with data. Some candidates found graphical analysis difficult and often used incorrect, computer generated graphs.

Fewer schools than in previous years made extensive use of worksheets, but there was still a tendency to overdo computer sampling at the expense of more traditional methods of obtaining data.

In the respect of worksheets, if a worksheet gives all the instructions necessary to assemble the apparatus for a particular experiment and also tells the candidates what readings of which quantities they should take, then this experiment cannot be used for the assessment of Planning skills.

Students should also be taught the correct application of error analysis and also how to make a quantitative evaluation of a particular experiment. For example, a candidate who carries out an experiment to measure g and comes up with a value 9.73 ms^{-1} and then writes something to the effect "the actual value of g is 9.81 ms^{-2} so therefore there is an error in my result of x%, so all in all this has been successful experiment", clearly has no idea of the correct way to assess errors or how to make a quantitative evaluation of procedure.

Candidate performance against each criterion

Planning (a) and Planning (b)

Students often do not perform well with Planning skills. This is often due to the type of experiments that some teachers submit as evidence of assessment of the Planning criteria.

For assessing Planning, teachers need to give the candidates more open-ended tasks. For example instead of just giving them instructions to measure that acceleration due to gravity using a simple pendulum, the candidates can be asked to investigate the factors (or one factor) that affect the period of a simple pendulum. In such an experiment the candidates have to identify the factor(s), hypothesise as to the possible outcome, identify the variables to control and then design a suitable method to carry out the investigation. Experiments that are designed to measure a specific quantity or that set out to verify a physical law or relationship do not allow candidates to formulate a research question or hypothesis and in most cases, the variables are prescribed. For example, experiments such as "To measure the wavelength of laser light" or "to verify Snell's law" do not lend themselves to the assessment of planning skills.

If candidates are given too much information about an experiment in respect of the apparatus, methods and procedures to use, or if they are directed to a reference that gives an account of the experiment, then this experiment cannot be used to assess Planning (b). Students must choose the apparatus and decide for themselves, the method and procedures to use. This also means that they must work on their own and as such, means that the Group 4 Project is not usually suitable for assessing either of the Planning criteria or for that matter, Data Collection.

For the moderator to make an accurate assessment of the teacher marking of the Planning Criteria, it is essential that a copy of the instructions given to the candidates is enclosed with the sample material.

Data Collection

This is usually well done except in some cases where data is very poorly presented. The data should, where appropriate, be put into a table and units and uncertainties should be included. Students should be taught that every measurement that they make involves an uncertainty! Also, if candidates are given a headed table on a worksheet as part of an experiment, then this experiment cannot be used to assess data collection. Also, it should be born in mind that experiments such as plotting magnetic field lines are not suitable for assessing this criterion. For Physics, the experiment should involve the collection of quantitative raw data.

Data Processing and Presentation

This was often poor. Students should be taught how to transform their data into a form that makes for good graphical analysis. The concept of error bars would appear to be alien to many candidates If candidates are told how to present the data, then they cannot gain a complete on the second aspect of this criterion. Too often one sees the instruction given to candidates "plot a graph of … against …."

Students rely too often, on computer graphing without clearly understanding what they are doing. They are the under the impression that if the computer gives them an equation for their graph, the regression and error bars, then this is good data presentation. In respect of error bars on computer generated graphs, the candidate must make it clear to the moderator, the basis upon which the error bars have been generated.

When graphical analysis is not involved, candidates still lost marks through poor, and in some instances, incomprehensible presentation of their data.

Again, experiments used to assess this criterion, should involve quantitative data.

Conclusion and Evaluation

This was often weak. In many cases, the conclusion was omitted and rarely was the problem of the limitations of a particular technique addressed. Furthermore, candidates rarely suggested possible improvements to the experiments or identified any possible weakness in the techniques used. The idea of repeating the readings as an improvement to the experiment, is often missed.

The recommendations for the teaching of future candidates.

The recommendations are essentially given above. However, to summarise:

- Choose appropriate experiments to assess correctly, the respective criteria
- Include the instructions given to the candidate for each experiment including a summary of any verbal instructions
- Get candidates to present data neatly, (use a ruler to draw tables) including units and uncertainties
- Make sure that candidates become familiar with graphical analysis techniques and present any analysis in a neat and logical manner
- Make sure that candidates always present a definite conclusion, assess limitations of the techniques used and suggest ways of improving the experiment.
- For the assessment of Pl(a), Pl(b) and DC, candidates should ideally work individually. If the candidates work in a group, then the individual work of the candidate must be identified in the work submitted for moderation.
- DPP and CE must be individual work.
- If two or more teachers are involved in the assessment of IA, then it is imperative that the work is moderated internally before any samples are sent to the moderator.

Teachers are strongly advised to note the guidance in the online Teacher Support Material phases 1 and 2 available on the Online Curriculum Centre (OCC) when setting and assessing practical work for the Group 4 Internal Assessment Scheme. Internal Assessment moderators will, in future be taking this guidance into account in their moderation of IA sample work from schools.

This year most 4/PSOW forms were completed correctly by the teachers but some schools are still sending complete portfolios of all the candidates in the sample and others, one complete portfolio.

Paper 1

Higher level paper 1 component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-15	16-21	22-25	26-29	30-33	34-40

Standard level paper 1 component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-11	12-14	15-17	18-19	20-22	23-30

General comments

IB multiple choice physics papers are designed to have, in the main, questions testing knowledge of facts, concepts and terminology and the application of the aforementioned. Although the questions may involve simple calculations, calculations can be assessed more appropriately in questions on Papers 2 and 3. Calculators are therefore neither needed nor allowed for Paper 1. A proportion of questions are common to the SL and HL papers, with the additional questions in HL providing further syllabus coverage.

The number of G2's received was small, 15 for HL and 28 for SL. The replies indicated that the May 2004 papers were generally well received. Approximately 80% (at HL) and 95% (at SL) of the teachers who commented on the Papers felt that they contained questions of an appropriate level. A small number thought that both Papers were a little more difficult. With few exceptions, teachers thought that the Papers gave satisfactory or good coverage of the syllabus (95% at HL and 90% at SL). However, it should be borne in mind that overall coverage must be judged in conjunction with Paper 2. All teachers also felt that the presentation of the Papers was either satisfactory or good.

Statistical analysis

The overall performance of candidates and the performance on individual questions are illustrated in the statistical analysis of responses. These data are given in the grids below.

The numbers in the columns A-D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank. The question key (correct option) is indicated by an asterisk (*). 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. A higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates.

SL Paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	404	1002*	1340	719	19	29	.28
2	247	216	2814*	200	7	81	.19
3	2346*	131	369	611	17	68	.32
4	365	229	2357*	530	3	68	.33
5	433	2458*	225	361	7	71	.32
6	1353	395	488	1241*	7	36	.39
7	254	1294*	331	1593	12	37	.30
8	1014	1037	1362*	68	3	39	.25
9	42	2973*	389	79	1	85	.22
10	1037*	119	2095	225	8	30	.15
11	485	1820*	1013	156	10	52	.44
12	1396	433	385	1254*	16	36	.42
13	2924*		352	203	5	84	.10
14	170	274	2948*	86	6	85	.31
15	377	611	75	2405*	16	69	.47
16	733	2450*	93	199	9	70	.37
17	456	1957*	732	329	10	56	.44
18	1567*	1140	366	402	9	45	.44
19	1297	1253*	315	606	13	36	.41
20	950	417	1871*	243	3	54	.41
21	2301*	522	406	241	14	66	.36
22	121	595	664	2097*	7	60	.49
23	407	261	1638	1169*	9	34	.25
24	56	2718*	23	666	21	78	.31
25	136	390*	2251	695	12	11	.08
26	1347	1530*	258	323	26	44	.36
27	795*	1144	781	741	23	23	.25
28	108	3079*	44	213	40	88	.22
29	602		421	2405*	56	69	.41
30	240	441	203	2539*	61	73	.46

In Q13 above, A and B were both marked correct and in Q29 B and D were both marked correct.

HL Paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	171	604*	573	270	12	37	.33
2	135	46	1375*	71	3	84	.17
3	1089*	50	116	371	4	67	.29
4	16	160	1370*	81	3	84	.27
5	123	1246*	123	136	2	76	.34
6	523	123	198	785*	1	48	.43
7	77	680*	117	752	4	42	.39
8	1236*	240	112	38	4	76	.26
9	100	1164*	313	51	2	71	.38
10	116	69	180	1264*	1	78	.44
11	86	449	825*	262	8	51	.51
12	617	128	511	371*	3	23	.28
13	444	79	218	884*	5	54	.31
14	42	1343*	110	129	6	82	.25
15	272	1257*	30	69	2	77	.33
16	130	1069*	320	104	7	66	.42
17	863*	447	184	132	4	53	.43
18	811*	163	133	521	2	50	.45
19	273	103	1156*	92	6	71	.29
20	1164*	194	162	101	9	71	.35
21	25	211	130	1263*	1	77	.35
22	387	141	289	802*	11	49	.54
23	396	163	892*	177	2	55	.04
24	463	422*	113	620	12	26	.16
25	9	1368*	17	233	3	84	.27
26	51	290*	1044	244	1	18	.22
27	549	871*	80	123	7	53	.34
28	786*	503	232	106	3	48	.32
29	405	76	1016*	124	9	62	.35
30	7	911	678*	28	6	42	.39
31	953*	338	291	37	11	58	.36
32	902*	95	481	137	15	55	.48
33	214		97	1310*	9	80	.29
34	88	176	75	1285*	6	79	.37
35	343	723	454*	85	25	28	.16
36	636*	540	399	38	17	39	.22
37	220	675*	688	40	7	41	.28
38	436	235	676*	273	10	41	.37
39	125	284	239	971*	11	60	.47
40	601*	470	195	349	15	37	.39

In Q33 above both B and D were marked correct.

Comments on the analysis

Difficulty. For both HL and SL the difficulty index varies from below 20% (relatively 'difficult' questions) to greater than 80% (relatively 'easy' questions).

Discrimination. All questions had a positive value for the discrimination index. Ideally, the index should be greater than about 0.2. This was achieved in the majority of questions. However, a low discrimination index may not result from an unreliable question. It could indicate a common misconception amongst candidates or a question with a high difficulty index..

'Blank' response. In both Papers, the number of blank responses increases for the last few items. This may indicate that candidates did not have sufficient time to complete their responses. However, this does not provide an explanation for 'blanks' early in the Papers. Candidates should be reminded that there is no penalty for an incorrect response. Therefore, if the correct response is not known, then an educated guess should be made.

Comments on selected questions

Candidate performance on the individual questions is provided in the statistical tables above, along with the values of the indices. For most questions, this alone will provide sufficient feedback information when looking at a specific question. Therefore comment will only be given on selected questions, i.e. those that illustrate a particular issue or where a problem can be identified.

Higher and standard level common questions

Higher and standard level question 7

It should be noted that it is common for scales to be calibrated in kg even though they measure weight. Although the vast majority of candidates realised that the elevator was moving upwards, they seemed to think that the acceleration was obtained by converting the scale reading into newtons.

Higher level question 21 and standard level question 22

Perhaps it might have been better to have specified an "isolated building" since, in a city, reflection would probably play a bigger role than diffraction. The diagram indicated an isolated building. However, both at SL and HL very few candidates chose the reflection distracter.

Higher level question 33 and standard level question 29

Several comments were received to the effect that the reaction given could happen in massive stars. In view of the fact that the question did not specify that the reaction took place in a laboratory, the Grade Award team decided to allow both B and D as keys.

Standard level questions

Standard level question 10

It is interesting to note that a large number of candidates (60% in this instance) continue to make the mistake of subtracting the two values for the momentum when attempting to find the impulse produced by a rebounding object.

Standard level question 11

There is a misprint in distracter D in which the subscript C is written as T, such that both forces are identical. A glance at the statistics would seem to show that this persuaded the candidates that this distracter could not be correct! A common mistake was to think that the relative magnitudes of the forces depend on the impact speed (distracter C).

Standard level question 12

Perhaps it might have been more precise to have asked for just "the work done by the machine". However, the only possible correct response is D and the answer chosen by 40% of the candidates was based on calculating 20% of the work done against gravity (A). This is clearly wrong.

Standard level question 13

In view of the fact that it was not made clear that the ball was thrown horizontally, it was decided by the Grade Award team to accept both A and B as keys. This now gives the question a difficulty index of 83.9%.

Standard level question 19

It is interesting to note that 37% of candidates thought that, to obtain the correct answer, the y-axis should be moved on by $\frac{l}{4}$. This was the same percentage as actually chose the correct answer (B).

Standard level question 23

There is evidence in this question, and elsewhere in the examination, that candidates are not aware of the rigour and precision demanded by definitions of physical quantities. The most popular choice for the definition of electric field strength was C which, although is consistent with the equation $E = \frac{F}{q}$, is not the definition until the terms are defined.

There was a teacher comment a propos this question and Q4 to the effect that electric field strength is not a vector quantity and that this could effect the choice of distracter. However, even if this statement is considered to be correct (and this is debatable), the best answer for both questions is as keyed.

Higher level questions

Higher level question 12

There were a few comments to the effect that the stem of this question was poorly worded. Candidates should be aware that the standard format for specifying a graph plot is "…the variation of y with x". In this respect the question cannot be considered to be badly worded.

Higher level question 23

It is worth mentioning that candidates should be aware of the effect (qualitatively) on the intensity of interference fringes when the distance between source and screen is increased.

Higher level question 26

There is evidence in this question and elsewhere in the examination, that candidates are not aware of the rigour and precision demanded by definitions of physical quantities. The most popular choice for the method by which the ampere is defined was C (64%). Although electric current is related to charge by the expression, this is not how the absolute unit, the ampere is defined.

Higher level question 28

Although the distracters A, B and C all show possible equipotentials, conventionally only A best shows the equipotentials associated with a point charge. As with contours or isobars on a map, one would expect that the change in value between neighbouring contours would be constant.

Higher level question 35

Judging by the number of candidates who gave B as the key, it would seem that a significant number (44%) were thinking of a photon.

Paper 2

Higher level paper 2 component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-11	12-23	24-33	34-44	45-54	55-65	66-95

Standard level paper 2 component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-18	19-23	24-29	30-34	35-50

General comments

The number of G2 forms returned by teachers was disappointing. Both Papers were thought to be of a similar standard to those in previous years, but a minority did think that they were a little more difficult. The papers were thought to be suitable by most teachers.

The areas of the programme that proved difficult for the candidates

For the SL Paper, question B1 was not popular and, as usual, candidates found the subject material to be difficult. This question also presented most problems in the HL Paper.

There is a general problem that is not specific to a particular subject area. Candidates lose far too many marks through poor wording of definitions. Definitions frequently lack precision and are expressed in non-scientific language. A thorough knowledge of such definitions is essential since, by their very nature, definitions are precise.

Graph plotting was disappointing and should have provided candidates with some relatively easy marks in question A1. This was not the case. Inappropriate scales, poor plotting and unacceptable lines were very common.

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

There were no areas of the examination where it could be said that all candidates appeared to be well-prepared. The more able candidates frequently showed some weaknesses. Less able candidates often scored the majority of their marks in a small number of isolated areas and did not attempt numerous parts of questions.

It was pleasing to note that, in question in Higher Level B2, part 1, question 2 (c) and in Standard Level B2 (d), the interpretation of the traces was good.

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

Section A

Question 1

Higher and Standard Level

(a) Graph plotting was, in general, disappointing. Candidates should choose a scale that is easy to read and one that cannot conveniently be doubled in size. Far too many scripts had scales that were either too small or attempted to use every square of the grid, thus giving rise to highly complicated scales. The plotting of the points was usually satisfactory.

(b) (i) The drawing of the curve left much to be desired. Candidates should realise that a single smooth curve is required. The use of a pen to draw such lines should be discouraged since correction is not possible.

(ii) There were many correct answers, within an acceptable tolerance. However, a significant minority of candidates changed appreciably the slope of their sketched line as soon as extrapolation was required.

(c) This part of the question gave rise to very few problems.

(d) (i) The candidates who were in error here were usually those who had devised difficult scales in part (a).

(ii) There was some confusion here as to what is meant by a percentage difference. Candidates should realise that, in the calculation, the original value should be in the denominator.

Higher Level Only

(e) (i) Most answers were acceptable. In general, the only problems were those associated with difficult scales.

(ii) Very few candidates made any comment as to whether a straight line could be made to pass within the tolerances for the three points. Instead, most stated that the points did not fit the straight line that had already been drawn on the grid.

Question 2

Higher and Standard Level

(a) With few exceptions, candidates took the horizontal component as being 8500sin14, rather than Rsin14.

(b) Answers here were disappointing. Most candidates attempted to calculate a resultant and ended up with the weight of the car. Very few realised that the answer in (a) was the resultant. Many did, however, give the correct direction for this resultant.

(c) For those candidates who were well-prepared, this calculation presented no difficulties. Others did not know what formula to use. A common error was to confuse the mass and the weight of the car.

(d) Most answers made some reference to the car tending to slide up the ramp. Very few gave a reason for this. Candidates should realise that a deduction requires some reasoning as well as the outcome. In this case, a reference to friction between the car and the slope would be satisfactory.

Higher level question 3

(a) There were some good answers here, related to the degree of disorder. However, many answers were confined to the molecules of a gas moving faster.

(b) It was common to find that no reference was made to total entropy. Furthermore, many candidates failed to read the question carefully and gave answers that did not refer to entropy change.

(c) Despite being told that the entropy of the egg decreases, many answers implied that the entropy would increase. Very few made any reference to the fact that the egg and its surroundings are the total system and that the entropy of the surroundings increases.

Standard Level Question 3

(a) Disappointingly, some candidates could not give the relevant formulae. Most calculations did not include a conversion of kJ to J and consequently, the answer obtained was 26 ms^{-1}.

(b) Any sensible comment and conclusion, based on the answer in (a), was allowed. Statements without any justification were not given credit.

Higher Level Question 4

(a) Most answers involved a quote of the de Broglie formula, with or without explanation. However, few were able to comment on the wavelength as being associated with the wave-like properties of any particle.

(b) A significant minority of candidates appeared not to understand the approach required for this calculation. Of those who could give relevant formulae, many made errors in the numerical manipulations, resulting in ridiculous answers. Candidates should be encouraged to consider whether an answer is reasonable. A quick check of the number processing can result in a higher score of marks.

Section B

Question 1

Higher and standard level

Not a popular question.

(a) There were very few correct responses to this part. It appeared that candidates did not appreciate what is involved in the earthing of a conductor or that, for an isolated conductor, charge must be conserved. The diagrams represented a standard example of charging by induction.

(b) (i) Definitions were, in most cases, very imprecise and often did not even make reference to work done. It is essential that candidates give precise clear definitions of basic quantities.

(ii) With very few exceptions, answers were attempted without reference to the diagrams in (a). The fact that the leaf deflected when the rod was moved, thus being associated with work done (not charge) was not appreciated. Likewise, the deflection of the leaf did not correspond with the charge on the electroscope.

(c) (i),(ii) and (iii) There were some well-presented and completely correct responses to these calculations, but such answers were in a minority. It was common to find that, for weaker candidates, they attempted to substitute into the equation force = energy/distance. Others used the equation E = P/I, without explanation.

Having calculated the current in the circuit, many candidates were unable to make any further progress.

(iv) Most answers did include a reference to electron movement in the resistor. However, rarely was there any mention of the lattice and the collisions of electrons within the lattice. Mostly, it was merely stated that the movement of the electrons would give rise to thermal energy in the resistor. The level of understanding of some candidates was illustrated by the fact that they thought that heat was produced by friction of the moving electrons.

Higher level

(d) (i) and (ii) Very few answers included clear statements of the laws. It was apparent that most candidates did not have clear ideas as to what was involved. Consequently, answers were, in general, imprecise and frequently violated fundamental principles of physics.

(iii) Very few candidates appreciated the fact that charge would be moved against the back e.m.f. induced in the magnet. Work would, therefore, have to be done and this work done is associated with the magnetic energy stored in the magnet. Candidates were informed that they should make 'reference to the induced e.m.f.' but very few followed this instruction.

Standard level

(d) Very poorly answered. In such questions, candidates should attempt to follow the sequence of energy changes. This was rarely apparent. Most mentioned some relevant forms of energy but were unable to make clear links between them.

Question 2

Higher level part 1

(a) (i) Most candidates were able to give a satisfactory answer.

(ii) Answers here were very poor. Many made reference to 'up-and-down' and 'side-to-side'. The question was worded to help candidates in that they were told to make reference to displacement. Of those who did include statements regarding displacement, it was usual to find that the displacement was given with respect to 'wave motion'. The term 'wave motion' is ambiguous – it could mean movement of a particle in the wave or the direction of movement of energy.

Standard level

(a) (i) Some candidates did include a satisfactory definition of what is meant by speed (including the ratio). However, very few made it clear as to what is moving. Many just mentioned 'the movement of the wave'.

(ii) Most candidates were able to give a satisfactory answer.

Standard Level (b) (i) Definitions were frequently very imprecise. For example 'distance moved' is unacceptable. In very few scripts was there a reference to distance from the 'mean position'.

(ii) Answers here were very poor. Many made reference to 'up-and-down' and 'side-to-side'. The question was worded to help candidates in that they were told to make reference to displacement. Of those who did include statements regarding displacement, it was usual to find that the displacement was given with respect to 'wave motion'. The term 'wave motion' is ambiguous – it could mean movement of a particle in the wave or the direction of movement of energy.

Higher Level Part 1 (b) and Standard level (c)

In general, the calculations caused very few problems, apart from mis-reading the graph or giving an incorrect unit.

Higher Level Part 1 (c) and Standard Level (d)

(i),(ii) and (iii) This was done well by most candidates. It was pleasing to note that, in the majority of scripts, three reasons were given.

(iv) A minority of candidates did calculate the distances and, in general, adequate explanation was given in these cases. In those scripts where the graph was used, explanations varied widely and many were muddled. Where a clear explanation was given, the distances were usually correct. Incorrect distances correlated highly with poor, or no, explanation.

(v) There was an element of guesswork here from weaker candidates who did, in fact, make totally unrealistic suggestions. Those candidates who produced reasonable (even if not correct) answers in (iv) were usually able to give an acceptable position for the site of the earthquake.

Higher level part 1 (d) and standard level (e)

(i) Very rarely was a diagram drawn that even vaguely resembled the representation of any standing (stationary) wave, either with a node or with an antinode at the base of the building.

(ii) Most candidates did determine the wavelength of the wave in the building. However, very few recognised the relation between the height of the building and the wavelength as having anything to do with a resonance effect. Some thought that the amplitude of vibration would be equal in magnitude to the wavelength.

Higher level only part 2

(a) Draughtsmen's drawings are not expected. However, candidates' work should be sufficiently precise to show the main features of what is being illustrated. Very few diagrams showed wavefronts that were sufficiently circular for any consistent change in wavelength to be seen in front of, or behind, the moving source.

(b) This part of the question should have been very straight-forward. However, many candidates did not even attempt it. Very rarely was a correct derivation seen.

(c) Again, many candidates did not attempt the calculation. Of those who did, most failed to convert successfully the wavelengths to frequencies for substitution into the standard formula.

Question 3

Higher and standard level

(a) (i) Candidates frequently failed to mention that, in fission, the fragments have similar masses and that, in radioactive decay, the nucleus emits a particle (α or β) and a γ -ray photon. It was common to find that either the element, or the atom or the isotope, rather than the nucleus, was involved in the processes.

(ii) Approximately 50% of answers were correct. The most common error was to show three, rather than four, neutrons on the right-hand side of the equation.

(iii) With few exceptions, this part of the question was answered correctly.

Higher Level Only (b)

(i) Very few answers attributed this energy to that of emitted photons or neutrons. Most thought that it was concerned with a mass defect.

Higher level (b)(ii) and standard level (b)(i)

There were surprisingly few correct answers. Some candidates were unable to identify the relevant equations. In many scripts where the equations had been written down, there were numerical errors.

Higher level (b)(iii) and standard level (b)(ii)

Again, there were very few correct answers where the momentum was attributed to either photons or neutrons. The most common answer was an explanation in terms of the difference in mass of the fission fragments.

Higher level (b)(iv) and standard level (b)(iii)

A large number of candidates showed the directions to be exactly opposite one another. This may be attributed to the fact that they did not appreciate the role of the emitted neutrons and/or the photons.

Higher level (c)

(i) Despite the fact that this should be a well-known definition, there were very few answers that could be given any credit.

(ii) In general, only weaker candidates could not make the necessary deduction.

Standard level (c)

(i) A common error was to use an incorrect value of the energy in MeV. There were the usual errors when converting MeV to joules but most candidates did manage to arrive at an answer, even if the answer was unreasonable.

(ii) This calculation was completed successfully by average and above average candidates. Weaker candidates often failed to start their answers by writing down an equation.

(iii) In those scripts where answers were obtained in (i) and (ii), then usually this part was completed successfully. Full credit was given in this part, even when the answers in (i) and (ii) gave rise to unreasonable answers.

Higher level only (d)

(i) In many scripts, this section was not attempted. There were some correct calculations but in most attempts, the candidates were unable to manipulate the exponential functions.

(ii) Most suggestions were very superficial – for example 'strontium lasts longer'. It was expected that reference would be made to activity and that it is the activity that gives rise to a health hazard.

Higher level only (e)

A comparatively small number of candidates gave a satisfactory response to all parts. Most candidates were unable to answer part (iii). Surprisingly, many were unable to identify the antinetrino.

Higher level only question 4

Part 1

(a) It should be realised that the gas equation must apply at all values of pressure, volume and temperature. Frequently, this point was missing.

(b) There was some doubt as to the meaning of specific heat capacity. For those candidates who wrote down a relevant equation, the calculation presented very few problems. Where an equation was not quoted, then errors such as using volume, rather than mass, were common.

(c) (i) In general, this calculation presented very few problems, apart from the situation where the temperatures were not converted to kelvin.

(ii) A clear statement of the relevant formula usually lead to a satisfactory conclusion.

(d) In the majority of answers, the correct conclusion was given. However, very few stated that the increase in internal energy would be the same at constant volume and at constant pressure.

Part 2

(a) (i) Most answers did not include a statement as to the initial position of the object that is escaping and they only considered the end-point.

(ii) There were very few satisfactory answers. It was expected that the necessary change in potential energy would be discussed and that this change was less than the available energy.

(b) (i) The majority of candidates failed to deduct the potential energy at the Earth's surface from the potential energy when in orbit. Consequently, there was an error in the denominator of the expression.

(ii) Disappointingly, most candidates did not work from an expression for centripetal force. Rather, they made a guess at the answer that was usually incorrect.

(c) Although most answers involved equating energies, explanation was poor and little progress could be made as a result of incorrect expressions in (i) and (ii).

(d) (i) It was expected that candidates would discuss the collisions of air molecules with the probe, resulting in kinetic energy being given to the air molecules with the consequent loss of energy of the probe. Alternatively, a treatment involving frictional forces was acceptable.

Answers tended to be very superficial, demonstrating a lack of understanding of underlying concepts.

(ii) Again, answers were very superficial.

(iii) With few exceptions, candidates realised that the radius of the orbit would decrease. Just as frequently, and quite wrongly, they thought that the speed would also decrease.

Recommendations and guidance that teachers should provide for future candidates.

Candidates should note the number of marks allocated to each section or subsection when considering the detail to be given in any answer. One-sentence answers are usually inadequate where several marks have been allocated. Furthermore, attention should be paid to the action verbs as listed in the Guide. In particular, where candidates are asked to 'state and explain' or to 'suggest', then a mere statement of the conclusion or a fallacious argument leads to no award for the conclusion.

General comments and non-scientific language are unacceptable when defining quantities and terms. Definitions, by their very nature, are precise. Candidates should be encouraged to develop a thorough knowledge of the bookwork. Without this thorough knowledge, understanding may be handicapped to such an extent that 'application' and 'extension' of the subject material are highly restricted.

Having completed any calculation, candidates should consider whether the answer is realistic, as well as giving it, with its unit, to an appropriate number of significant digits. Answers that are incorrect by many powers-of-ten are not uncommon and are easily corrected since they frequently originate from an incorrect unit (e.g. substitution of km rather than m).

Where diagrams and graphs are drawn, these should show the relevant important features. For example, spacing of wavefronts or straight lines. When drawing a graph, many candidates attempt to draw freehand any straight line using a pen. The result is that any error cannot be corrected and the line is inappropriate.

Paper 3

Higher level paper 3 component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-14	15-21	22-27	28-34	35-40	41-60

Standard level paper 3 component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-10	11-13	14-17	18-22	23-26	27-40

General comments

Whilst there were some challenging questions this year, the majority of candidates seemed to find the paper accessible and there were examples of good understanding of the material. 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 attention to the space available for answering particular sections of questions or to the marks available. Consequently, they gave needlessly lengthy answers to questions that were worth one mark and answered questions worth four marks with a simple multiplication of two numbers. Many candidates appeared not to know that their answers should be given in the spaces provided in the examination paper and, instead, used continuation sheets unnecessarily. A few candidates answered more than two Options and it was clear that some candidates answered Options for which they had not been prepared.

Candidates should to be encouraged to ensure that they have turned the page and answered every part of a particular Option question. Significant digit error and unit errors continue to decrease. This is a welcome trend in the pursuit of precision.

The majority of candidates showed the steps in calculations and so were able to take advantage of "error-carried-forward" marks and also for marks awarded for partially correct responses. However, a worrying number of candidates simply wrote down an answer to numerical calculations without any working being shown (often with multi-part calculation steps). Also, if candidates are asked to deduce that a particular value is correct, then clearly no marks can be awarded if no working is shown.
The feedback from teachers on the G2 forms for SL and HL can be summarized as follows:

Higher level

- About 60% found the paper to be of a similar standard to last year and 40% a little more difficult. However, overall, 77% found the paper to be of an appropriate standard and 23% thought it too difficult.
- About 47% found the syllabus coverage satisfactory and 38% good.
- About 31% found the clarity of wording satisfactory and 38% found it good.
- About 31% found the presentation satisfactory and 62% found it good.

As in previous years, the most popular options were H (Optics), G (Relativity) and F (Astrophysics).

Standard level

- About 70% found the paper to be of a similar standard to last year, 20% a little easier and 10% a little more difficult. However, overall, 80% found the paper to be of an appropriate standard, 12% thought it too difficult and 8% found it too easy.
- About 52% found the syllabus coverage satisfactory and 39% good.
- About 43% found the clarity of wording satisfactory and 48% found it good.
- About 35% found the presentation satisfactory and 61% found it good.

As in previous years, the most popular options were A (Mechanics) and H (Optics).

The areas of the programme that proved difficult for the candidates

A very prominent feature of this examination at both Standard and Higher Levels has been the striking lack of precision and detail in the definition of various physical quantities and description of phenomena. The definitions were either poorly expressed, incomplete, imprecise or just plain wrong. Examples include

- Gravitational field strength
- Half value thickness
- Retrograde motion

- Theories of electric charge
- Luminosity
- Apparent brightness
- Cepheid variables
- Postulates of relativity
- Relativistic mass
- Principle of equivalence
- Critical angle
- Diffraction in lenses
- The formation of coloured images by thin films.

As in past examinations candidates displayed weakness in the use of the lens equation and the various sign conventions associated with this equation. The use of moments in option A at Standard Level and option D at Higher Level was frequently incorrect.

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

They had a good understanding of the concepts and showed skill in problem solving, with good equation manipulation and attention to units and significant figures.

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

Standard Level

Option A: Mechanics

Question 1: Gravitation and orbital motion

The definition of gravitational field strength was often incorrect, but the arrows representing gravitational field strength and velocity and acceleration were mostly correctly given. It was pleasing to see a significant number of candidates performing the algebraic work correctly to obtain the answer to the gravitational field strength in the last part to this question.

Question 2: Frictional forces

This question was answered well by the majority of candidates. There was the occasional error of using the static coefficient of friction in calculating the acceleration of the block.

Question 3: Rotational equilibrium

The marks awarded here were either zero or four (the latter being the exception). Too many candidates attempted to obtain the answer as a ratio problem without writing down the torque equation. Many who did attempt to use torques did so incorrectly, and a large number of candidates used unconventional methods such as splitting the weight and having it act at different parts of the rod.

Option B: Atomic and nuclear physics extension

Question 1: The photoelectric effect

There were not many clear answers describing aspects of the photoelectric effect that could not be explained by the classical theory of light. In fact, most descriptions given here did not pertain to the photoelectric effect at all. In part (b) a disappointingly large number of candidates had problems when using the graph to obtain values for the critical frequency, the Planck constant and the work function. Very few candidates realised that the graph line for the second metal had to be parallel to graph line for the first.

Question 2: Particle physics

The answers to this question were rather disappointing. It was clear that the majority of candidates had no real understanding of the conservation laws being asked for, and most answers included permutations of the laws of conservation of mass, momentum and energy. Lepton number, baryon number and charge were seldom mentioned.

Question 3: Charged particles in a magnetic field

It was very pleasing to see that this was well answered. There were good derivations of the radius of the path of a charged particle in a magnetic field as well as of the mass of the second isotope and the nucleon structure of each.

Option C: Energy extension

Question 1: Wind turbines

Many candidates misunderstood the first part to this question and gave reasons why the efficiency could not be the maximum theoretical possible; the question was clearly asking for the factors affecting the efficiency. The importance of the advice to candidates to "read the question carefully" cannot be overemphasised. The second part to he question required careful numerical calculations and unfortunately the majority of the candidates who attempted this question got lost in the numbers.

Question 2: Heat engines

The first part to this question asked for the most straightforward energy flow diagram in a heat engine. This should have been an easy three marks for candidates but again, it was disappointing to see so many incorrect answers. The identification of various processes on the p - V diagram was not well done. Very few candidates could correctly use the efficiency formula and argue why the lower temperatures would result in a higher efficiency.

Higher and standard level

Option D: Biomedical physics

Question 1: Scaling

A small minority of candidates had practised scaling questions and did well. The rest of the candidates who attempted this question did not understand what was involved. As in previous years, the mark distribution was either all or nothing. It is surprising that even though the scaling law was given, very few candidates could use it to estimate the time for a child, given the time for the adult.

Question 2: Medical imaging

This was answered well but there was some confusion evident concerning the fact that X-rays are transmitted while ultrasound is reflected. Also, a minority confused ultrasound with sonar.

Many candidates obtained the metal thicknesses correctly. In the last part of the question, about 25% of the candidates set up a simple ratio assuming direct variation rather than an exponential relationship.

Higher level only

Question 3: Energy in the human body

Most candidates correctly defined “metabolic basal rate” but a few explained “basal” while neglecting “metabolic”.

The majority of candidates failed to name the mechanisms, and were vague in describing how they resulted in a loss of energy e.g. “sweating cools the body”.

Higher Level Only

Question 4: Forces in the human body

The majority of candidates answered this question well. In (b), a few knew that the distance from the pivot point was important, but did not describe this in terms of torque.

Option E: The history and development of physics

Question 1: Motion of the planets

Very few candidates drew diagrams to explain their answers. A good diagram often provides valuable assistance. In the explanations provided, most failed to mention that the apparent motion of the planet against the background of the "fixed stars".

Question 2: Electric charge

Very few candidates seemed familiar with the two fluid theory of charge. Most were conversant with electrons.

Question 3: Cathode rays

This section was answered quite well, except that very few knew about Hertz's work and Thompson's modification. The calculations that followed were generally well done.

Higher Level Only Question 4: Atomic models

The Bohr model was well understood but many candidates felt a limitation was the unexplained concept of "allowed orbits". Many candidates struggled in comparing Schrodinger's and Heisenberg's ideas.

Option F: Astrophysics

Question 1: Cepheids

A disappointingly large number of candidates could not give precise definitions of quantities such as luminosity and apparent brightness. The mechanism of Cepheid luminosity variation was well understood at the simple level of an expanding and contracting surface but most were not aware of the important relationship between period and luminosity. Most candidates were not aware of the term "standard candles".

Question 2: The Big Bang model

This part was generally well done except that most candidates cited "expansion of the universe" without providing any evidence for it such as for example the redshifted light from distant galaxies. Again the answers lacked detail as for example in the definition of the cosmic background radiation. The part about the "universe expanding into a vacuum" was answered well by many who gave the standard Big Bang model answer. There was no evidence whatsoever that candidates who were familiar with string theories, M-branes, multiple universes etc through articles in scientific journals were, in any way, disadvantaged by this question.

Higher level only question 3: galaxies

Most candidates answered this section correctly. There were amusing diagrams of the Milky Way galaxy!

Option G: Special and general relativity

Question 1: Effects of special relativity

This was very straightforward although “inertial” was frequently omitted in (a). The speed of light was seldom specified to be that in vacuum. About one-third of the candidates were confused by the terms “correct” and “proper”. The question of the time recorded by the spacecraft observers in (b) (v) was answered correctly by only a handful of candidates. Even though the distance between the Earth and the spacecraft is 4.8 ly at the time of the signal emission (as far as the spacecraft is concerned) the Earth is moving away and so the signal has to “catch up” resulting in a large time of arrival. This means that this problem can be solved with simple kinematics without use of relativity equations once it is realized that the signal is approaching Earth at the speed of light. Of course the problem can also be done with the time dilation formula but only when a proper time interval is correctly identified. This problem shows the clear misconception (that must be rectified in teaching) that the “moving frame of reference always measures proper time intervals”. This is incorrect because there is no such thing as the moving frame of reference. Students should also be encouraged to do calculations using the light year as the unit of distance. In many situations it is much faster and safer.

Question 2: Relativistic mechanics

Rest mass was frequently described without reference to an observer. In (b), a majority of candidates showed a curve continuously increasing rather than essentially horizontal until near the vertical asymptote. It is important to realize that, in the limit of small velocities, the relativistic and Newtonian curves agree. About half of the candidates correctly related the difference to increase in mass rather than simply the inability to exceed c. A minority explained that Newtonian physics required a linear relationship.

Higher level only

Question 3: General relativity

Most candidates did well in this question and used good arguments to support their answers. A small number of candidates confused the equivalence principle with the special relativity postulates.

Option H: Optics

Question 1: Critical angle

A majority missed the fact that the critical angle can only occur when the light is travelling from a dense medium to a less dense medium. The critical angle is the angle of incidence (between the normal and incident ray) and, for the critical angle, the refracted ray travels along the interface. Section (b) was difficult to grade since the candidates were determined to find some way to convert 1.2 km into 1.8 km. Some, without justification, simply multiplied the index of refraction by the length. Others embarked on lengthy solutions without reference to diagrams and the use of undefined variables. The diagram showed only the internally reflected ray and not the ray refracted at . This did not appear to confuse any candidates. Almost no one had difficulties with (c).

Question 2: Lenses

The majority of candidates had trouble with the lens equation. The sign conventions are clearly not well understood by the candidates. The syllabus includes the study of lens combinations and this cannot be done without discussion of, for example, virtual objects. Very few could explain correctly why the addition of the diverging lens increased the focal length of the system.

Question 3: Spherical aberration

Most candidates could draw the image correctly but could not explain how to reduce spherical aberration.

Higher level only

Question 4: Optical resolution

Almost no one thought of diffraction as the source of the problem. There seems to be some confusion here. Students think that diffraction will only take place when the wavelength of light is comparable to the aperture size. Since the wavelength of light is small compared to the diameter of a lens, then no diffraction is expected. This, however, is wrong. A lens that is aberration free will always produce an image of a point source that is not a point but the result of some kind of diffraction pattern. The central part of this image is always a bright spot (the Airy disc) that is surrounded by a dark ring. The angular diameter of the dark ring is given by where b is the lens diameter. Even though the details of this derivation and the theory of this kind of diffraction are beyond the level of this course, these bare facts are on the syllabus and candidates should be aware of them. In the second part to the question, there was also some confusion between radians and degrees. The Rayleigh criterion was well-known and about half of the candidates carried out the calculation correctly.

Higher level only

Question 5: Thin film interference

This was very disappointing. Very few candidates scored marks here. Very few could correctly identify interference as the source of the coloured images. Most based their answers on dispersion. There is some evidence that teaching time is running short when this part of the syllabus is reached and that this topic is somewhat neglected.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team included the following ideas:

- It is important that Options are not left until the end of the course. This can lead to their study being rushed or incomplete. The time available for the study of the Options should be allowed for and carefully integrated into the programme as a whole. Candidates should not attempt to answer an Option that they have not studied.
- If candidates study an Option on their own, then teachers should ensure that their progress is carefully monitored and that adequate support is given. Students from a school that answered questions in the same two options generally performed better than those that answered questions from several different options.
- Candidates should read the question paper through before starting, not only to gauge the variety of questions but also the number of sections in each question and the difficulty before choosing and starting.
- Candidates should read each question carefully. Answers must be focused – there is no need to write unnecessarily long sentences. Students must learn to answer precisely what the question asks.
- Candidates must ensure that they are familiar with the definitions of physical quantities. The definitions must be precise, accurate and detailed.

- Candidates should use the amount of marks allotted a given part of a question as a rough guide to the amount of detail required in their answers.
- Candidates should be encouraged to produce clear and labeled diagrams.
- Candidates should check their answers and see if they make sense. Two points at the back of the eye cannot be separated by 5 m and the distance to a star cannot be .
- Candidates should be familiar with the contents of the Data Booklet. Discovering what it contains during the actual IB examination is not a good idea.
- Answers must be written in the appropriate space on the examination paper itself.
- When a sketch graph is asked for, the graph must show sufficient detail. If the line to be drawn is a straight line the use of a straight edge is very useful.
- More practice is needed with the interpretation of data – particularly when the data is presented in graphical form.
- Practice with the manipulation of ratios both in numeric and in symbolic form.

