PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-28	29-40	41-51	52-62	63-73	74-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-29	30-42	43-53	54-61	62-72	73-100

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.
Comments provide valuable information to the Grade Award team in respect of the determining of grade boundaries. These comments are also used as future reference for paper writers. While most comments are specific there has been a tendency towards generalities in the comments on some G2 forms. Teachers are encouraged to be specific about their comments. For example, the comment 'not clearly worded' is of limited value, both to the Awarders and to the paper writers. In this instance, the particular aspect that is not clear should have been stated.

Paper 1

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

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 -10	11-14	15-18	19-21	22-25	26-28	29-40

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 these aspects. Although the questions may involve simple calculations, calculations can be assessed more appropriately in questions on Papers 2 and 3. Calculators are, therefore, neither necessary 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, 17 for HL and 23 for SL. With such small numbers, doubt is cast on whether these numbers do provide a representative sampling of all Centres. The replies indicated that the Papers were generally well received. 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 too difficult. However, the mean mark for each Paper was very similar to the mean for last year. With few exceptions, teachers thought that the Papers gave satisfactory or good coverage of the syllabus. It should be born in mind that coverage of the syllabus must be judged in conjunction with Paper 2. It is not expected that complete coverage will be provided in an individual Paper. All teachers thought 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
13	16	17	11	435*	4	90.06	.17
19	418*	13	41	8	3	86.54	.27
11	34	13	387*	48	1	80.12	.35
3	16	20	60	385*	2	79.71	.29
24	107	335*	27	11	3	69.35	.35
29	56	35	329*	56	7	68.11	.53
10	75	309*	59	40		63.97	.27
18	72	298*	29	84		61.69	.40
30	298*	94	37	43	11	61.69	.48
2	35	71	104	272*	1	56.31	.39
22	58	90	62	272*	1	56.31	.44
15	43	102	263*	73	2	54.45	.34
8	62	110	253*	57	1	52.38	.36
25	68	84	71	249*	11	51.55	.36
23	118	7	246*	107	5	50.93	.39
21	52	100	241*	88	2	49.89	.19
5	32	239*	163	48	1	49.48	.36
26	40	113	239*	86	5	49.48	.48
20	63	34	164	220*	2	45.54	.36
28	89	124	215*	45	10	44.51	.44

9	167	208*	63	43	2	43.06	.39
16	77	196*	153	53	4	40.57	.12
4	246	190*	35	11	1	39.33	.47
12	175*	183	15	108	2	36.23	.19
14	37	96	168*	180	2	34.78	.16
7	48	240	49	143	3	29.60	.49
17	132*	75	163	112	1	27.32	.25
27	169	117*	109	77	11	24.22	.26
6	259	108*	71	42	3	22.36	.37
1	30	87*	235	125	6	18.01	.03-

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
5	383*	12	23	1	2	90.97	.11
2	7	10	55	349*		82.89	.30
36	31	344*	16	27	3	81.71	.24
19	41	326*	24	30		77.43	.37
21	51	27	18	324*	1	76.95	.35
11	316*	76	4	25		75.05	.33
22	80	313*	4	22	2	74.34	.35
35	300*	63	25	29	4	71.25	.33
26	48	268*	82	19	4	63.65	.44
32	29	88	40	261*	3	61.99	.41
14	258*	88	42	32	1	61.28	.44
4	45	11	108	256*	1	60.80	.25
28	66	64	34	256*	1	60.80	.30
30	27	88	252*	54		59.85	.40
34	52	86	242*	36	5	57.48	.35
20	55	229*	41	94	2	54.39	.45
27	36	83	229*	72	1	54.39	.35
7	49	92	227*	50	3	53.91	.36
9	113	223*	68	17		52.96	.45
31	45	217*	72	80	7	51.54	.27
12	107	58	216*	39	1	51.30	.42
29	82	65	53	213*	8	50.59	.42
40	61	210*	65	79	6	49.88	.40
38	100	81	32	202*	6	47.98	.48
13	115	58	197*	45	6	46.79	.36
23	63	24	138	191*	5	45.36	.41
25	45	142	53	180*	1	42.75	.18
39	81	180*	84	68	8	42.75	.61
18	67	175*	126	51	2	41.56	.27
33	152	174*	75	17	3	41.33	.36
10	161*	166	22	68	4	38.24	.17
6	197	154*	38	31	1	36.57	.56
8	161	153*	49	53	5	36.34	.38
16	24	63	151*	180	3	35.86	.20
15	29	32	145*	212	3	34.44	.31
17	128*	68	163	61	1	30.40	.28

3	78	29	121*	192	1	28.74	.40
37	119*	165	106	21	10	28.26	.35
24	40	118*	169	89	5	28.02	.35
1	19	75*	175	145	7	17.81	.05-

Comments on the analysis

Difficulty. For both HL and SL, the difficulty index varies from approximately 18% to approximately 90% (relatively 'easy' questions). The majority of questions lie within the range 30% - 73%. This wide range of difficulty is intentional so that candidates of differing abilities will be spread throughout the mark range for the Paper. Some difficult questions are necessary to distinguish between the most able candidates.

Discrimination. Apart from the most difficult question on each Paper, all questions had a positive value for the discrimination index. Ideally, the index should be greater than about 0.20. However, questions with a very high or a very low difficulty are likely to have a discrimination of less than 0.20. Furthermore, a low discrimination index may not result from an unreliable question. It could indicate a common misconception amongst candidates. A satisfactory discrimination was achieved in the majority of questions.

'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. Candidates should be advised against leaving any questions unanswered.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.

SL and HL common questions

SL and HL Question 1

This question had the lowest Difficulty Index in both papers. Candidates are expected to be able to describe liquids and gases in terms of molecular structure and motion. At SL and HL, candidates should have an understanding of relative molecular separation that extends beyond the most elementary level e.g. 'further apart'. As a teaching point, when considering evaporation, the comparison of the volume of unit mass of liquid water and of steam will give an estimate of the relative separations of molecules in the two states. Furthermore, the densities of liquids are about 10^3 times the densities of gases, once again leading to an appropriate comparison.

SL and HL Question 6

Disappointingly, the most popular option was A and thus the Difficulty Index was low. In practice, this question was not difficult but candidates needed to think about the situation rather than rush into the giving a well-trodden generalisation.

SL Question 9 and HL Question 8

Although the statistics for this question were satisfactory, the wording of the stem would have been improved if the word 'defines' had been shown in bold type. However, candidates should realise that Paper writers intend that every word in a question is of importance and should be read as such.

SL Question 12 and HL Question 10

Opinion was divided, to a great extent, between the correct response and the distractor B. Candidates should be encouraged to realise that an acceleration does not always imply a change of speed and thus a change of energy.

SL Question 14 and HL Question 16

The most popular distractor was D. This indicates a lack of understanding of basic thermometry on the part of candidates.

SL Question 17 and HL Question 17

A difficult question. The Discrimination Index was quite satisfactory, indicating that the more able students did, in general, give the correct response.

SL questions

Question 4

A question that proved to be quite difficult but, at the same time, had a very high discrimination. The use of velocity vectors is seen as being a difficult topic in Papers 1 and 2 for less able candidates.

Question 7

As was to be expected, the most popular response was Option B. The vector nature of momentum can never be over-emphasised.

Question 27

The statistics would indicate that, although more able candidates could complete the question successfully, there was much guesswork amongst the less able candidates. This was a question involving resultants. The most popular distractor implied that the Earth's field would no longer exist.

HL Questions

Question 3

It is interesting to note that the most popular response corresponded to the addition of the two quantities. Candidates should realise that the difference between two measurements will give a large uncertainty compared to that where the measurements are added.

Question 15

The most popular response was D where it would seem that weaker candidates failed to consider that the lines of action of the forces were not parallel. Judging by the Discrimination Index, this was not a problem for more able candidates.

Paper 2

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	27-31	32-37	38-50

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-11	12-22	23-35	36-46	47-57	58-68	69-95

General comments

The G2 forms suggested that both Papers were thought to be of a similar standard to those in previous years, but a very small minority of teachers did think that they were a little more difficult. Most teachers thought that the syllabus coverage, clarity of wording and presentation was either satisfactory or good.

The areas of the programme that proved difficult for the candidates

- Candidates had difficulty with describing, in terms of energy changes, the molecular behaviour, of water and steam during heating.
- Generally, both HL and SL were not good in dealing with algebraic data. This was highlighted in the question about deducing the law of conservation of momentum. Candidates should appreciate the use of algebra gives a general solution of a problem and is a very powerful tool in physics.
- SL candidates found the vector addition of fields difficult.
- HL candidates had difficulty with the topics of Gravitation, Electromagnetic induction and the wave nature of matter.
- There is a general problem that is not specific to a particular topic area. Candidates lose far too many marks through poor wording of definitions and/or laws. These frequently lack precision and are expressed in non-scientific language e.g gravitational field strength, Newton's third law, conservation of momentum. A thorough knowledge of such definitions is essential since they provide an understanding of the concepts that they define and thus, need to be precise.
- Many candidates also found explanations of physical phenomena difficult, relying more on anecdote than principles of physics.
- Candidates should also know that the final numerical answer to a calculation must be given to the number of significant digits consistent with the given data.

- Candidates should also be encouraged to set out their method used in calculations. If a method is not clear or not given and the final answer is incorrect then "error carried forward marks- ECF" cannot be awarded.

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

Most candidates showed good graphing skills and were confident with applying the correct formula. Omission of units seemed to be less of a problem than in previous years.

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

Section A

A1 (HL and SL)

Data Analysis.

(a) In (i), most candidates read the graph correctly. In (ii), weaker candidates did not appreciate what equation to use ($F = \mu N$, $F = ma$ often being quoted). Many also failed to convert kilowatts to watts.

(b) The graphing was done well by most candidates. In fact, weaker candidates scored the majority of their marks for the whole Paper on this part. Several candidates quoted the power obtained from the graph as xx P/kW.

(c) **HL only** Many candidates did not apply logs to the equation correctly in order to show that the value of n is obtained from the gradient.

A2 (SL only)

Standing waves in pipes.

(a) Surprisingly, a significant number of candidates appeared to be unaware of the representation of a stationary wave. For the open pipe, many failed to indicate antinodes at both ends of the pipe.

(b) There were many correct answers in (i) from those who could draw the appropriate standing wave in (a)(i). Others merely calculated the wavelength.
In (ii), most were able to state that the closed pipe would be shorter. However, many failed to consider the data given in the question, that is, a frequency of 32 Hz.
Candidates were expected to comment on the fact that the wavelength (or length of pipe) of an open pipe would be longer than a pipe closed at one end.

A2 (HL only)

Trajectory motion

Several candidates made this unnecessarily complicated and got bogged down in a maze of arithmetic. Also a common mistake was to not resolve the velocity or resolve it incorrectly. Otherwise, the question was often quite well-answered.

A3 (HL) and B2 Part 1 (SL)

Energy changes in an escalator

Most parts were often done well with the exception of calculating the minimum power, understanding why the weight of the escalator does not have to be taken into account and identifying where friction losses occur. In respect of the latter, too many answers just said "lost as friction" or "lost as heat, light and sound" or were totally irrelevant e.g. "because more people might get on the escalator". The action verb associated with this part of the question is "explain" not "state".

A4 (HL only)

Wave nature of matter.

(a) Quite a few candidates quoted $\lambda = \frac{h}{p}$ as the de Broglie hypothesis but failed to define the terms.

(b) The calculations were often done well but also quite often left unanswered.

This would appear to be a topic that candidates either knew well or not at all.

Section B

B1 (HL and SL)

Part 1 Specific heat capacity and specific latent heat

(a) Definition of specific heat were usually correct. However, candidates should be encouraged to give definitions in terms of unit quantities, rather than actual units.

(b) Few candidates understood the reason why the specific heat capacity of different substances are not equal in value. Many tried to answer in terms of molecular bonds. Few referred to change in kinetic energy of molecules or the different number densities of atoms/molecules. More able candidates frequently made a reference only to density difference.

(c) In general, the sketch graph showed a discontinuity at the correct position. However many lines either started at the origin or showed heating of steam alone.
In(ii), answers were frequently disappointing. Most candidates did make reference to increase in kinetic energy as the temperature rose. However, although it was realised by most that, at 100 °C, the kinetic energy would no longer increase, many failed to mention change in potential energy. Frequently, the change of phase was dismissed as either 'breaking bonds' or 'atoms moving apart', rather than a clear treatment of both aspects together with a comment on change in potential energy.

(d) In (i), with few exceptions, adequate explanation was given.
There were some good, well-explained answers in (ii). The weakest candidates merely calculated the energy required to raise the temperature of the whole mass of water. Others assumed that all the energy provided would be used to evaporate water at 100 °C.

Part 2 (SL)

Radioactivity and nuclear energy

(a) As always in such questions about isotopes, there was confusion between nuclei, neutrons, nuclides and isotopes. Candidates should realise that they should refer to the similarity of, and difference between, several nuclei and not just refer to one single nucleus.
When defining half-life, most candidates realised that something would halve. Candidates should be encouraged to be precise and to refer to either the activity, or the number of nuclei, of that particular isotope and certainly not the mass.

(b) With few exceptions, the equation was completed correctly and a sensible graph was drawn. Despite the fact that the time scale on the *x*-axis was unusual, most gave a value of activity within reasonable limits.
The experiment was poorly described with very few scoring any marks. It was necessary to refer to suitable apparatus (e.g. Geiger tube and counter) and that the source must be close to the tube. Some experimental detail as regards finding the count-rate was expected (e.g. take count for specified time and divide count by time).

(c) Surprisingly, there were few arithmetical errors in the calculation. Candidates divided into two groups; those who understood the task and those who appeared not to have studied the topic.

Part 2 (HL)

Radioactivity and nuclear energy levels.

(a) Radioactive half-life was often incorrectly defined in terms of the mass decreasing by half. Candidates should be encouraged to be precise and to refer to either the activity, or the number of nuclei, of that particular isotope and certainly not the mass.
Few candidates appreciated that the decay constant is the probability that a nucleus will decay in unit time.

(b) Many candidates tried to bluff their way through the proof of $\lambda T_{½} = \ln 2$.

(c) The activity calculation defeated a lot of candidates usually because they seemed unfamiliar with handling exponential calculations.

(d) The calculation of the energy and frequency of the γ-ray photon were often done well.

(e) The concept of nuclear energy levels seemed unfamiliar to quite a few candidates. Few could make the connection between the difference in energy states and the data given in the calculation.

B2

HL B2 Part 1 (SL B2 Part 2)

(a) Part (i) was poorly answered. Very few realised that the specification is for a lamp at normal, and not maximum, brightness and so failed to make the connection between the power dissipation in the filament and normal brightness
The calculation of the current in (ii) was accomplished correctly in most scripts.

(b) The explanations in (i) indicated that very few candidates had a clear understanding of the situation. Most mentioned internal resistance but the concept of the supply voltage being divided between the internal resistance, variable resistor and lamp escaped most candidates. However, a few had the idea that internal resistance played some part in the answer as to why zero and 3.0 V cannot be obtained across the lamp.

The calculation in (ii) was completed successfully by quite a few candidates although explanation was frequently lacking and left the impression that perhaps candidates did not fully appreciate what they were doing.

(c) There were very few errors in these straightforward calculations.

(d) Only the most able candidates could give an explanation in terms of the heating of the resistor and the consequent rise in resistance.

(e) Sketches were disappointing with few being acceptable. Many showed the current approaching infinity. Others indicated that, for larger values of V, the current would be constant. There were also a lot of sketches showing ohmic behaviour.

(f) Weaker candidates did not appreciate that a parallel combination of resistors was involved. Others calculated the value of the combined resistance of the lamp and YZ but could go no further. There were, however, some well-explained calculations that used various routes in particular, division of voltage and division of current.

Part 2 (HL only)

Orbiting satellite

This was generally not well answered with most marks being gained in the first parts of the question. These parts essentially involved standard bookwork. However, few definitions of field strength made reference to a point mass or small mass (see comments above).
There were some very confusing attempts at showing that the kinetic energy of the satellite is numerically equal to its potential energy. The final problems were often left unanswered.

B3
Part 1 (SL and HL)

Conservation of momentum and energy

This question was structured to lead candidates through what is essentially a standard piece of bookwork. However, responses were very disappointing and often very weak.

(a) Many were content to state ‘action and reaction are equal but opposite’. It is necessary to discuss the magnitude and direction of the two forces and the bodies on which the forces act.

(b) Again, definitions lacked precision. A statement such as ‘in any collision, momentum is conserved’ is insufficient. The fact that no external forces act on the system is important, as is a specification of the direction.

(c) Some diagrams lacked detail, such as the arrows being of equal length. A common error was to show the arrows above the spheres, rather than along the lines of action of the forces.

(d) This part of the question was poorly answered. Frequently, there was no indication of which force was involved and the direction of any change in momentum was not clear.

(e) Most candidates had little idea as to how to proceed. This was due mainly to the failure to give appropriate expressions in (d).

(f) Most candidates wrote down a correct expression related to conservation of kinetic energy. Others also wrote down an expression related to conservation of momentum but rarely could candidates proceed further.

Part 2 (SL only)

Electric charge at rest

(a) Many candidates referred to 'force on a charge' rather than 'force per unit charge' in the definition of electric field strength (see comments above) and then failed to specify the sign of the charge.

(b) A clear derivation was required. Many did not give an expression relating r and a. Consequently, the derivation was not adequate.
In (ii), the majority did give the correct direction.
The derivations in (iii) were disappointing. Rarely was it made clear that components were being added vectorially. The lack of explanation in the candidates' working made the awarding of "ECF" marks difficult (see comments above).

Part 2 (HL only)

Electromagnetic induction

This was generally not answered well. For example Faraday's law was rarely stated correctly. Also many candidates thought that the right hand rule is used to determine the direction of an induced current; rarely was Lenz's law invoked.
Whether the poor performance in this question was due to a lack of understanding of the topics addressed or to lack of knowledge, is difficult to conclude. However, in view of the large number of candidates who left this part of question B3 unanswered, the examiners are inclined to the latter conclusion.

B4 (HL only)

Part 1

Wave properties and interference

The parts of the question on standard wave properties (a), (b) and (c), were often answered well. Quite a few candidates did not get the direction of the marker correct with many showing it moving along the wave. Also, a significant number of candidates did not draw the wave a quarter period later.

(d) Many candidates stated the principle of superposition in terms of amplitude additions instead of the addition of displacements.

(e) The part on interference was reasonably well done but a common error was to omit the small angle approximation. In the calculation, many candidates did not follow the instruction given in the question and used the data book formulae to find the values of wavelength and fringe separation.

Part 2

Thermodynamic process

This question was often answered well.

Several candidates did not know what an adiabatic process is and/or could not recognise the process given as being neither isothermal nor adiabatic. However these candidates often went on to do the calculation correctly.

Recommendations and guidance that teachers should provide for future candidates

Some of what follows is a summary of the comments above.
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 leads to no marks. Also, a fallacious argument leading to the correct conclusion obtains no marks..
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 e.g. spacing of wavefronts or straight lines. When drawing a graph, many candidates attempt to draw freehand lines using a pen. The result is that any error cannot be neatly corrected.

Paper 3

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-11	12-16	17-20	21-23	24-27	28-40

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-8	9-16	17-23	24-30	31-36	37-43	44-60

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 brief sentence.

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.

Standard Level

- 50% found the paper to be of a similar standard to last year, 10% a little easier and 40% a little more difficult. However, overall, 90% found the paper to be of an appropriate standard but 10% thought it too difficult.
- 92% found the syllabus coverage either satisfactory or good.
- 92% found the clarity of wording satisfactory or good.
- 100% found the presentation satisfactory or good.

As in previous years, the most popular options were A (Mechanics) followed by H (Optics) and F (Astrophysics). It was pleasing to see a significant number of centres choosing option D (Biomedical Physics).

Higher Level

- 62% found the paper to be of a similar standard to last year and 31% a little more difficult. However, overall, 81% found the paper to be of an appropriate standard and only 19% thought it too difficult.
- 88% found the syllabus coverage either satisfactory or good.
- 100% found the clarity of wording satisfactory or good.
- 100% found the presentation satisfactory or good.

As in previous years, the most popular options were H (Optics), F (Astrophysics) and G (Relativity). It was pleasing to see a significant number of centres choosing option D (Biomedical Physics).

The areas of the programme that proved difficult for the candidates

As in the May session, 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 the definitions or statements of the following:

- Newton's law of universal gravitation
- Coefficient of friction
- Half life
- Decay constant
- Adiabatic change
- Attenuation coefficient
- Half-value thickness
- Magnitude (apparent and absolute)

- Postulates of Special Relativity
- Principle of equivalence
- Refractive index (very poorly done)
- Monochromatic
- Coherent

As in past examinations many candidates displayed weakness in the drawing of a ray diagram

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

Many candidates who attempted option F (Astrophysics) were well prepared and often could follow the calculation through to the end. Calculations associated with option D (Biomedical Physics) were also done well.

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

SL only

Option A – Mechanics

Question 1 Gravitation and ocean tides

Only a handful of students referred to point masses when quoting Newton's law of Universal gravitation, but many made reasonable attempts at the explanation of tides.

Question 2 Friction

Students had difficulty defining the coefficient of friction and could not produce a convincing argument why the static coefficient of friction should be used in part (b). Many muddled the forces acting on the person with, not surprisingly, many identifying the horizontal force acting on the person as a centripetal force as opposed to a normal reaction from the wall. The subsequent calculation was often muddled.

Option B - Atomic and nuclear physics extension

Question 1 Quark Structure

This question tended to be done well especially the balancing of quark types in part (c).

Question 2 Photoelectric effect

The initial parts of this question were done well on the whole but the answers to the final section on the wave nature of particles was rather disappointing. The majority of candidates referred to experiments involving light as opposed to particles.

Question 3 Radioactivity

It was very pleasing to see that this was on the whole generally well answered. There were good calculations of the time taken for the activity to be reduced to a given level.

Option C - Energy extension

Question 1 Diesel engine and the Carnot cycle

Many candidates failed to do well in this question. Few could successfully define the Carnot cycle and most calculated the efficiency using temperature in degrees Celsius.

Question 2 Production of electrical energy

The first part to this question asked candidates to consider energy changes in power stations. This was done well though many were unable to provide the detail required for the function of the moderator and control rods in nuclear reactors.

SL and HL combined

Option D - Biomedical physics

Question 1 Scaling

This year candidates performed well on this section. Although some mathematical mistakes were made, many were clearly using the correct approach to solve the problem.

Question 2 X-rays

The lack of precision and detail was particular evident in the first two parts of this question. Many candidates knew something about each of the situations discussed but very few could gain full marks for their answers. In part (c), which was concerned with the attenuation of X-rays by bone, fat and muscle, the calculation in part (i) was done well but few candidates used their answer to this part to help them answer part (ii) which considered the fat-muscle boundary.

AHL

Question 2 (continued)

Many were able to get some credit for the mathematical answers to this section but the detail was again missing in the descriptive sections. Almost everybody failed to get the correct unit for the absorbed dose and very few at all made any sensible estimate for the mass of the upper part of the body of the patient. It was very common to see candidates substituting the total mass of the patient in (d)(ii).

Option E – The history and development of physics

Question 1 Cathode Rays

Most candidates could identify the correct hypothesis implied by the experimental evidence supplied but justifications tended to be weak. Similarly many descriptions of an experiment to measure the charge-to-mass ratio for an electron showed some idea of the principles involved but often lacked detail.

Question 2 Astronomical observations

Surprisingly few candidates were able to gain significant credit for this very straightforward question. For example, in part (c) candidates were asked to explain the path of the Sun using different models of the universe. Instead of explaining the path, many candidates gave general descriptions of the models involved.

AHL

Question 3 Atomic spectra

This question asked candidates to apply the Rydberg formula to the Balmer series. Many seemed to understand the general principles involved but once again failed to include the appropriate detail in the descriptions or in the calculations.

Option F – Astrophysics

Question 1 Properties of the star Arcturus

A disappointingly large number of candidates could not give a precise definition of the term *apparent magnitude*. Many of the descriptions of the method for measuring stellar distance lacked precision and many of the diagrams were not sufficiently labelled. The remaining parts of the question involving calculations were generally done well.

AHL

Question 2 Galaxies

Many candidates were content to answer part (a) by returning the information given in the question. This approach did not gain any credit. Hubble's law was generally well known but many candidates simply quoted the formula without defining any symbols. Part (b)(ii) asked for the experimental measurements required in order to determine the Hubble constant. A lot of candidates were content to state that velocity and distance were needed but failed to identify the actual physical measurements that should be taken.

Many made reasonable attempts at the calculation of recession speed but a large majority muddled the units. Few were able to correctly calculate the age of the universe from the Hubble constant.

Option G - Special and general relativity

Question 1 Postulates of special relativity

Candidates seemed to be aware of the two postulates of special relativity but typically failed to specify that the speed of light in a vacuum was constant. Many also forgot to specify that the frames of reference involved are all inertial. The rest of the question tended to be answered reasonably well.

Question 2 Relativistic motion

The calculations required for this question were generally done well and it was pleasing to see the students that did attempt this question demonstrating a good understanding of the principles of special relativity.

AHL

Question 3 Relativistic collision

The initial calculation required for this question was either done well or not at all. Many candidates missed the subtlety of the need to conserve both momentum and energy in the collision.

Question 4 General relativity

The common failing in this question was the lack of sufficient detail. Although specifically asked to do so in the question, the vast majority of candidates failed to refer to the equivalence principle in their explaining of *gravitational lensing*.

Option H – Optics

Question 1 Human eye

This question did not expect candidates to have studied the workings of the eye but used this system as an example of the action of a lens. In drawing the ray diagram, most candidates did not show parallel rays from the distant object thought many were able to produce a diagram correctly locating the image of the object used by the candidate. The use of the lens equation caused the majority to make mistakes. The final part (d), which was concerned with the refraction taking place at the cornea, was done poorly. Few candidates related refractive index to the speed of electromagnetic waves and those who referred to Snell's law failed to define the angles involved. Finally many candidates wrongly considered the refraction from air into water as opposed to the refraction taking place as a ray enters the eye at the water – cornea boundary.

Question 2 Waves

The majority of students were unable to define the terms *monochromatic* and *coherent* but most could make a reasonable attempt at completing the table of properties of different waves. Most could state an application of Laser light but often did not provide sufficient detail to unambiguously identify the application.

AHL

Question 3 Diffraction grating

Very few candidates could explain the production of the spectra by the diffraction grating in any detail though a greater number of candidates could correctly use the diffraction grating formula to calculate the angle of the first order maximum.

Question 4 Rayleigh criterion

Many candidates had some idea of the Rayleigh criterion but their answers often lack precision. Part (b) asked candidates to estimate the diameter of the eye but many used the equation $\theta \approx 1.22\frac{\lambda}{b}$ to calculate a value for the aperture diameter. They were then unable to decide if the two sources could be resolved in part (c).

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team included the following ideas:

- Candidates should be encouraged to be precise at all times. It would help if their practice work under examination conditions was assessed using the same criteria as the final examination. Definitions that have some idea of the concepts but fail to be detailed and precise do not receive full credit, often they do not gain any marks.
- Candidates need to be familiar with the action verbs as defined in the syllabus guide. All IB questions use these action verbs and the required detail of the answer is specified by the action verb used in the question.
- 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 level.
- Candidates should read each question carefully. Answers must be focussed – there is no need to write unnecessarily long sentences. Students must learn to answer precisely what the question asks.
- Candidates should use the amount of marks allotted to 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 labelled diagrams.
- Candidates should check their answers and see if they make sense. The aperture of a human eye cannot be 2×10^3 m nor can the age of the universe be 5.314 years!
- 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.

Internal assessment (higher and standard level)

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 tremendous range of work submitted this year, with practical programs ranging from extraordinary to less than acceptable. Most schools are covering a fair range of topics and meeting the time requirements. Core material, additional higher material and the options have all been addressed and there were some good physics experiments that were not strictly within the course syllabus. This diversity should be encouraged. Many schools are using computers and interfaces, graphing programs and word processing in their lab work. There were also a number of low-tech but equally challenging investigations. Planning (a) investigations were generally relevant and students responded well to them. The group 4 projects were also reasonably done. There were many examples of good high school level practical work, and in most cases the work was suitable for IA assessment. As expected, the majority of investigations were not assessed by the formal IA criteria. Examples of where assessment was made but the assignment was not suitable for proper assessment include the following: planning (a) topics that were given to the student, or where the student was asked to confirm Newton’s second law or to find the refractive index of glass; Planning (b) assignments where students were given standard experimental equipment; Data Collection where students were given tables; and Data Processing and Presentation where students were told what to graph.

Candidate performance against each criterion

Planning (a): Performance of this criterion has seen improvement over the last few years. Teachers are following examples from the OCC teacher support material. There are still examples of where the teacher asks students to confirm the conservation of momentum or to find the specific heat capacity of water as a planning (a) investigation. Planning (a) investigations need to be open-ended, and textbook equations should not be used to formulate a hypothesis.

Planning (b): There should be a variety of methods and techniques demonstrated here, and standard class sets of equipment are not normally appropriate. Students must determine what to do under planning (b).

Data Collection: This is the easiest criterion to achieve full marks on. The occasional teacher, however, still hands out a data sheet with units, columns and roles for data. The student must decide what data to record and how to record it. Raw or absolute uncertainties must also be recorded with each set of data. In physics, data is always quantitative, at least as far as IA assessment is concerned. Hence, drawing water wave patterns is not appropriate for data collection.

Data Processing and Presentation: Students need to be encouraged to make more use of graphs. Some students are still connecting the dots on a graph. Proper graph technique should be emphasized. Although error bars are used by some students, more attention to this is needed. Finally, some teachers assess DPP when they tell the student what to graph. This is not appropriate. When computer software is used, students need to appreciate what is truly meaningful and what is not.

Conclusion and Evaluation: Although the assessment criteria here are nicely spelled out, many students ignore some or all of the aspects when writing their conclusions. It turns out that this criterion, along with planning (a), are the most difficult to achieve full marks. Students really need to look as each aspect of the IA criterion when writing conclusions.

Recommendations for the teaching of future candidates

- Teachers should carefully study the IA descriptors when assigning investigations that are to be evaluated by them.
- Students should have copies of the IA descriptors when writing up investigations.
- Teachers should encourage students to process data with graphs, and to use correct graphing techniques. Drawing graphs using computer software is not discouraged, but care needs to be taken to ensure that the criterion are fully accessible to the student.
- Errors and uncertainties need more attention.
- The group 4 project is often inappropriate for assessment because students work in teams.
- Teacher instructions are required for investigations that are being moderated. Teachers who forget to include these make it difficult for the moderator to determine what the student truly did and what was given to them by the teacher.

Further comments

Although the quality and extent of work from schools varied widely, it is safe to say that the majority of students are doing good high school level physics practical work. It is also encouraging that, overall, the IA criteria are being followed. Some teachers still don't follow the IA requirements, making mistakes on the 4/PSOW or forgetting to include teacher instructions. A few schools demonstrate unusual imagination when it comes to time allocation. Hooke's law was given 19 hours of class time at one school, and another school claimed 5 to 8 hours per lab. Overall, a careful reading of the IA criteria would help both teacher and student.

