PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-26	27-37	38-48	49-58	59-70	71-100

Overall grade boundaries

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-25	26-35	36-47	48-57	58-69	70 -100

Higher and standard level internal assessment

Component grade boundaries

Higher level

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

Component grade boundaries

Standard level

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

The overall impression is that the IA program is clearly understood and working well. There was a noticeable improvement with planning (a) investigations, and there was the obvious influence of the OCC on teacher's work. The range and suitability of student investigations was good, although mechanics is usually overemphasized. Teachers must try to have practical work in all major syllabus areas, including the options.

Candidate performance against each criterion

Planning (a)

There are still a few cases where students are at a disadvantage because the teacher does not give them a fair opportunity at planning an investigation, for example, when told to find the specific heat capacity of an unknown substance. Appropriate planning topics are open-ended situations where students should be looking for a function or relationship between two variables and not a particular value. The teacher may instruct the student to choose both the independent and dependent variables, or the teacher may tell the student the dependent variable (as long are there are various possibilities for independent variables). If the teacher gives the student the research question, hypothesis and variables, then the moderator must mark it down to a not-at-all. Under the second aspect of planning (a), a student must come up with a hypothesis or prediction related to the research question. In physics, this needs to be quantitative, often in the form of y = mx + c. Some physical explanation is expected.

Planning (b)

The success of planning (b) often depends upon a clearly understood research question and the identification of the variables under planning (a). When all the students in a class use the same method then a moderator is alerted to the possibility of inappropriate teacher instruction. Teachers must not tell the student what materials or methods to use and students must address the scope and range of data they plan to take in order for the third aspect to earn a complete.

Data Collection

In physics, all raw data has associated uncertainties that should be indicated in the data table. To earn a complete, students must record units and uncertainties and also show consistency of significant digits between uncertainties and recorded raw data. Teachers must not tell the students what data to record and when a photocopied data table is provided the criterion must be marked as a partial + not at all.

Data Processing and Presentation

Graphing programs are encouraged but if not used then graph paper should be used for graphing results. Free-hand graphs are not acceptable in physics. Students must not be told how to process the data. Graphs should include a best straight-line, and if raw data is used then uncertainty bars for one of the quantities is expected. At higher level, students are expected to construct minimum and maximum gradients as well as the best straight-line and the range between the minimum and maximum gradients should be used to establish an experimental uncertainty in the best straight-line gradient. At standard level, a best-fit line graph is sufficient to meet the requirement of error and uncertainty appreciation.

Conclusion and Evaluation

This is often difficult for students because the student must relate back to the original research question and the experimental results. A valid conclusion is one that appreciates the quality of the data and the scope and limit of the investigation. The graph(s) need to be appropriate. Moreover, for a complete some physical explanation is expected. The evaluation of the procedure and results should have both quantitative and qualitative observations. Suggestions for improvement need to be relevant and realistic.

Recommendations for the teaching of future candidates:

- Group 4 projects are often the result of a team effort and so these projects are normally not appropriate for assessment by any of the first five criteria. They may be assessed under the non-moderated criteria of Manipulative Skills and of Personal Skills (a).
- The open-ended nature of planning (a) investigations needs to be appreciated by both the teacher who sets the prompt for the investigation and for the student.
- Teachers and students need to be aware of the difference between the expectations (based on the syllabus) between standard and higher level students when it comes to the handling of errors and uncertainties.

- More teaching is needed in the area of graphing skills, including the treatment of errors and uncertainties in graphs.
- The continued use of the IB's Online Curriculum Centre is encouraged. It is evident that many teachers are making good use of the resources here, especially the planning investigations.

The overall evidence is that internal assessment of the physics program is clearly understood by the majority of teachers and students, and that the application of the IA criteria is done in a satisfactory way. The vast majority of 4/PSOW and the new 4/IA cover sheet forms have been correctly followed. It is hoped that the additional general comments in the above report will prove helpful to new and experienced teachers.

Higher and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-14	15-18	19-22	23-26	27-30	31 -40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-14	15-17	18-20	21-23	24 -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 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, 21 for HL and 30 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 (95% at HL and 97% at SL). About 20-21% of the G2 forms indicated that the papers were a bit harder than last year's. Teachers thought that the papers gave satisfactory or good coverage of the syllabus (57% and 43% respectively at HL and 37% and 60% at SL). Teachers thought that the presentation of the papers and the clarity of the wording was either satisfactory or good (95% at HL and 97% at SL).

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 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	192	21	356*	31		59.33	0.32
2	45	292	120	140*	3	23.33	0.23
3	66	131	310*	91	2	51.67	0.67
4	62	401*	33	103	1	66.83	0.57
5	135	257	164*	39	5	27.33	0.40
6	48	251	287*	12	2	47.83	0.48
7	275	68	89*	165	3	14.83	0.21
8	288*	162	107	42	1	48	0.25
9	186	51	326*	37		54.33	0.49
10	92	137*	307	63	1	22.83	0.30
11	77	322*	105	82	14	53.67	0.47
12	35	143	96	324	2	54	0.42
13	483*	46	33	37	1	80.50	0.21
14	108	220	244*	27	1	40.67	0.40
15	115	38	340*	105	2	56.67	0.30
16	24	442*	34	100		73.67	0.32
17	271	18	284*	25	2	47.33	0.51
18	326*	173	53	47	1	54.33	0.60
19	142	76	211	166*	5	27.67	0.50
20	218*	332	30	19	1	36.33	0.33
21	72	221*	156	150	1	36.83	0.41
22	122	103	163	196*	16	32.67	0.37
23	153	262	30	152*	3	25.33	0.30
24	131	70	362*	30	7	60.33	0.39
25	233*	136	88	132	11	38.83	0.44
26	37	344	163*	46	10	27.17	0.36
27	107	151	127	201*	14	33.50	0.32
28	76	381*	85	42	16	63.50	0.36
29	119	110	265*	99	7	44.17	0.40
30	93	112	333*	48	14	55.50	0.41

Number of candidates: 600

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	130	7	296*	17		65.78	0.31
2	20	212	75	142*	1	31.56	0.35
3	55	163*	196	34	2	36.22	0.31
4	157	38	39	216*		48	0.17
5	71	172	173*	34		38.44	0.46
6	122	39	246	42	1	54.67	0.27
7	75	166*	185	22	2	36.89	0.38
8	230	42	86*	91	1	19.11	0.23
9	118	16	292*	23	1	64.89	0.37
10	52	272*	67	54	5	60.44	0.39
11	27	109	93	220*	1	48.89	0.37
12	255*	130	23	42		56.67	0.51
13	36	263*	79	66	6	58.44	0.45
14	22	301*	73	54		66.89	0.39
15	48	223*	57	119	3	49.56	0.36
16	61	134	225*	30		50	0.52
17	8	378*	17	47		84	0.29
18	10	96	139*	205		30.89	0.27
19	125	54	214*	57		47.56	0.33
20	30	226*	67	126	1	50.22	0.31
21	201	7	238*	4		52.89	0.31
22	318*	105	16	10	1	70.67	0.49
23	94	275*	38	40	3	61.11	0.51
24	225*	88	119	17	1	50	0.51
25	190*	241	9	8	2	42.22	0.34
26	210*	21	184	34	1	46.67	0.60
27	85	175	17	172*	1	38.22	0.35
28	126	140	138*	44	2	30.67	0.12
29	45	276	97*	32		21.56	0.37
30	109	53	136	151*	1	33.56	0.29
31	188*	249	6	6	1	41.78	0.45
32	126	101	172*	42	9	38.22	0.38
33	100	199*	32	116	3	44.22	0.25
34	210*	168	42	27	3	46.67	0.39
35	82	43	23	298*	4	66.22	0.52
36	52	46	231*	113	8	51.33	0.44
37	58	64	242*	85	1	53.78	0.29
38	92	126*	66	164	2	28	0.37
39	72	49	288*	40	1	64	0.51
40	81	93	58	217*	1	48.22	0.44

Number of candidates: 450

Comments on the analysis

Difficulty. For both HL and SL, the difficulty index varies from approximately 19% (relatively ‘hard’ questions) to 84% (relatively ‘easy’ questions) for HL and from approximately 15% to 80% for SL.

The majority of questions lie within the range 45% - 60%. 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. 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. All SL questions do have a difficulty index greater than 0.20 and the same is true for all the HL questions except for two (questions 4 and 28). A low discrimination index may indicate a common misconception amongst candidates.

'Blank' response. At SL there is an increase in the number of blank responses indicating that perhaps candidates felt they were running out of time. There was no corresponding increase at HL. 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

Question 7 SL, Question 8 HL

This proved to be a difficult question at both levels with the majority of candidates choosing option A. The scale measures the force acting on it and that force is the reaction force R. Presumably most students realized that the reading of the scale would be larger than the weight of the body and so chose $R + W$.

Question 9 SL, Question 9 HL

The Spanish edition of the paper contained the word "momento" which is what the syllabus guide uses for momentum. The literal translation of the word did not cause any problems to the candidates according to the statistics for the question.

Question 10 SL, Question 7 HL

The question asked for what happens after the fan is turned on and the air is incident on the sail. With the air incident on the sail there are no external forces and so the total momentum of the cart-air system stays zero i.e. the cart does not move.

Question 18 SL, Question 22 HL

The question had a high discrimination index but many students made the common mistake of thinking that the cork would be carried forward by the wave and so chose option B.

Question 23 SL, Question 27 HL

The majority of candidates chose option B presumably misled by the fact that the conducting sphere was uncharged. They neglected to take into account the charge separation that takes place when the charged sphere is brought nearby.

SL questions

Question 6

This was an unambiguous question. The cannon is mounted vertically on the cart (this is stated in the question and is shown in the diagram) and so there is only one way the ball could be launched out of the cannon, namely vertically with respect to the cart.

Question 8

It was good to see many candidates realizing that since the bodies are in free fall, the tension in the string is zero.

Question 19

This was a difficult question. But students only needed to compare the distance between points P and Q to the wavelength of the wave in order to deduce that the displacement and velocity of point Q were both opposite to those of P.

Question 22

The statistics of the question shows that students were clearly guessing at this question.

Question 26

It was disappointing to see so many candidates choosing option B. They naively doubled the power because the voltage doubled without realizing that with a constant resistance, the power dissipated is proportional to the square of the voltage.

HL Questions

Question 4

This was a question with a low discrimination index (0.17). Many candidates chose option A, implying that they assumed that the displacement graph was a parabola, which it was not. In any case, the slope of the graph is clearly *decreasing at a non-constant rate* and approaches zero so that D is the only possible response.

Question 12

The Spanish translation of this item was slightly different from the English version. The statistics of the question reveal that no candidate was disadvantaged in any way.

Question 20

As always, questions must be read carefully. The question stressed the word “ideal” by placing it in bold face. The use of bold face is made sparingly so that candidates can be alerted to the precise meaning of a term. Being ideal, the gas could not have had its internal energy changed in the free expansion into the larger container.

Question 28

This proved to be a difficult question with a low discrimination index (0.12). The statistics shows that many candidates were guessing at the answer. The question referred to electric potential, a scalar quantity, and so it should not have been too difficult to find where the potential from the four charges adds to zero.

Question 29

The great majority of candidates chose option B. When lamp N burns out the total resistance of the circuit changes and so the current through M changes. Thus option B is easily eliminated. This difficult question discriminated well between the strong and the weak candidates.

Question 30

This was another difficult question with good discrimination. The statistics indicates that many students were guessing here.

Question 33

The photon moves at the speed of light and so does not have a rest frame. Therefore there is no reason to distinguish between rest mass and mass in this case.

Question 38

This was a difficult question with good discrimination. The majority of nuclei have the same density because the radius of a nucleus of nucleon (mass) number A is proportional to $A^{\frac{1}{3}}$.

Higher and standard level paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-21	22-31	32-41	42-52	53-62	63-95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-9	10-15	16-21	22-27	28-32	33-50

General comments

The number of G2 forms returned by teachers was disappointing. Examiners do take into consideration the views of teachers. However, where so few forms are returned, there is much doubt as to whether the forms are a representative sample or are views of a minority who have a particular view to express. There were 28 forms completed for SL and 18 forms for HL. Teachers who commented on the papers felt that they contained questions of an appropriate level (89% at HL and 82% at SL). 50% at HL and 38% at SL of the G2 forms indicated that the papers were a bit harder than last year's. Teachers thought that the papers gave satisfactory or good coverage of the syllabus (44% and 50% respectively at HL and 39% and 61% at SL). Teachers thought that the presentation of the papers and the clarity of the wording was either satisfactory or good (89% at HL and 95% at SL).

The areas of the programme that proved difficult for the candidates

- In general, candidates failed to score what should be 'easy' marks for definitions. These were frequently imprecise or incomplete. In some cases, they were completely incorrect.

- SL candidates found the graphical addition of vectors addition to be difficult. Problems also arose with mass defect, electrical circuits and radioactivity.
- HL candidates showed very little knowledge of the mass spectrometer. Low marks were scored when answering the question on the interference of waves and on the photoelectric effect.
- Many candidates also found explanations of physical phenomena difficult, relying more on anecdote than principles of physics.
- Candidates should appreciate that the final numerical answer to a calculation must be given to the number of significant digits consistent with the given data. Units are also required.
- Candidates should also be encouraged to set out their calculations to indicate clearly their working. If a method is not clear or not given and the final answer is incorrect then "error carried forward' marks cannot be awarded. In physics examinations, the method of working may well be more important than the final numerical answer.

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

Most candidates showed an improvement in their understanding of data analysis. As usual, the question on dynamics was popular but this popularity did not necessarily indicate a high success rate.

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

Section A

A1 (HL and SL) - Data Analysis

(a) (i) With few exceptions, the line was drawn in the correct position.

(ii) Most candidates did draw an acceptable tangent. However, it was common to find that this was drawn at 50 °C, rather than at an excess temperature of 50 degrees C.

(b) (i) Surprisingly, some candidates did not mark in the point at the excess temperature of 50 degrees C.

(ii) A minority of candidates drew the error bars parallel to the temperature axis. However, the majority drew error bars of an acceptable length.

SL only

(c) A significant number of candidates made reference to a straight line graph but did not draw such a line of the graph. Those who did draw a line frequently made a reference to the scatter of points.

Fewer considered that, for the expression to be valid, the line must pass through the origin. Proportionality is shown by a straight line passing through the origin. Linearity requires only a straight line.

HL only

(c) (i) A significant number of candidates made reference to a straight line graph but did not draw such a line. Those who did draw a line frequently made a reference to the scatter of points. Fewer considered that, for the expression to be valid, the line must pass through the origin. Proportionality is shown by a straight line passing through the origin. Linearity requires only a straight line.

(ii) Those candidates who did attempt to draw a straight line of best fit were in a position to answer this question. However, few commented that, at higher excess temperatures, the points were further from the line of best fit.

(d) (i) There were many correct sketches with acceptable straight lines.

(ii) Where answers were given to this section, most stated that the gradient would be 1.0. However, few correctly related the value of *k* to the antilog of the value of the intercept on the lg*R* axis.

A2 (HL only) - Nuclear and particle physics

(a) Despite the fact that the schematic diagram of a spectrometer is specified in the Guide, most diagrams were so poor as to be unrecognisable. Any type of spectrometer would have been accepted. Clearly, this topic had not been given due emphasis in the teaching.

(b) In some answers it was realised that a magnetic field would give rise to different deflections. However, diagrams showing these deflections were seldom realistic.

(c) These three answers should have been given correctly by most candidates since they are factual knowledge. Indeed, they presented no difficulty for some candidates. However, it was clear that a significant minority had little appreciation of the topic.

A3 (HL only) - Temperature, internal energy and thermodynamics

(a) The question could be answered on the basis of macroscopic properties (mass and specific heat capacity) or microscopic properties (random kinetic energy and potential energy of atoms).

Answers were frequently either limited to the mention of one relevant point or were confused by introducing both approaches.

(b) (i) There were many correct responses. A common error was a failure to state that it is the entropy of the Universe – rather than a specific object – that must increase. Candidates should be warned that a statement that entropy does not decrease is not the same as stating that entropy always increases.

(ii) In most answers, it was stated that the (freezing) water would lose entropy. The reason for this was not always made clear. Although it was usual to state that the surroundings would gain entropy, many failed to state that the gain would be greater, in magnitude, than the loss.

(c) (i) With few exceptions, the change was identified as being adiabatic.

(ii) In many instances, candidates attempted to describe changes in all four changes, rather than concentrating on what was required.

A2 (SL only) - Vectors

(a) In general, answers were disappointing with many candidates not knowing where to start. Those candidates who followed the instruction to draw a scale diagram usually completed the work successfully. It was expected that, since the question is based on a common laboratory exercise, many more candidates would have been familiar with the situation. The graph grid was provided so that it was not necessary for candidates to construct angles.

(b) There were some very good suggestions, based on the fact that there must be a vertical component of tension in the string. On the other hand, there were some attempts that bore no resemblance to the outlined situation.

A3 (SL only)

Again, there were a number of good answers. However, many did not appreciate what was expected of them. In such questions, candidates should be encouraged to commence their answers by defining the relevant quantities. In this case, the starting point was to explain what is meant by internal energy.

A4 (SL only)

(a) Definitions tended to be imprecise, without any clear reference to nuclei and the fact that the nucleons must be separated completely. There is confusion between the terms isotope, nucleus, nucleon and nuclide.

(b) The serious problem here was that candidates did not appreciate that the mass defects were *per nucleon*. Instead, the values were assumed to be the mass defect of the nucleus.

Section B

B1 (HL and SL) Part 1 - Linear motion

(a) Definitions of acceleration were usually correct. However, candidates should be encouraged to give definitions in terms of unit quantities, rather than actual units, and to clearly indicate that a ratio is involved.

(b) The assumption was stated correctly in most scripts. It was surprising that even some of the less-able candidates could complete the derivation. Candidates should be encouraged to explain their working. All too frequently, the answer amounted to a mass of algebra, without any reference to the physics of the situation.

(c) (i) Apart from a failure to convert the distance fallen from cm to m, there were very few problems with this part of the calculation.

(ii) Although there were many correct solutions, there were significant numbers that indicated a lack of understanding of the situation. A common error was to assume that the ball had fallen 12 cm from rest.

(HL only)

(c) (iii) In general, it was realised that the ball would fall a greater distance while the shutter was open. However, few went on to state that this would lead to a smaller fractional uncertainty in the measurement.

(HL and SL)

Part 2 - Collisions

(a) The situation was not understood by the majority of candidates. They failed to appreciate that the ball is travelling in the arc of a circle and therefore there must be a centripetal force provided by the cable. Consequently, many calculations were erroneous and a considerable proportion did not even include the weight of the ball.

(b) With few exceptions, candidates realised that the simplest method involved the calculation of an area. The most common error was a failure to give the time of contact as 0.15 s.

(HL only)

(c) The calculations presented few problems apart from the unit of momentum.

(d) In general, the discussion did not relate well to the definition. Despite having made reference to a ‘closed system’ many then failed to state what comprised the system.

(e) This calculation was completed successfully by the majority of candidates.

(SL only)

(c) The calculation presented few problems apart from the unit of momentum.

(d) In general, the discussion did not relate well to the definition. Despite having made reference to a 'closed system' many then failed to state what comprised the system.

(e) This calculation was completed successfully by the majority of candidates.

B2

HL only

Part 1 - Gravitation

(a) Despite being told to explain the reasoning, the majority of answers were without any explanation.

(b) The calculation presented few problems.

(c) The formula was given correctly in most scripts. The situation as regards the change in energy was not appreciated by many. A common misunderstanding was to state that, by conservation of energy, the kinetic energy and hence the speed must increase because the potential energy has decreased.

(d) Escape speed was frequently defined without any reference to the point at which the speed is measured.

(e) As in other calculations, the mathematics was usually appropriate but again, explanation was sadly lacking.

(f) The calculation presented few problems.

(g) There were unexpected numbers of errors of substitution, particularly as regards the mass of a helium-4 atom, giving rise to wholly inappropriate answers.

(h) Many candidates were able to express, in a variety of ways, the idea that the atoms would have a distribution of speeds.

Part 2 - Electromagnetic induction

(a) Disappointingly, many calculated the flux rather than the flux linkage.

(b) A failure to distinguish between flux and flux linkage led to confusion in (i). However, despite poor statements of the law, most could calculate the e.m.f.

(c) Statements were usually acceptable. However, in (ii), the origin of the force on the moving coil was not identified.

B3 (HL) - Travelling waves

B2 (SL)

(a) (i) Most answers made a clear reference to transfer of energy.

(ii) The error in the labelling of the *y*-axis meant that a variety of answers for the amplitude were accepted so that no candidate was disadvantaged. The section presented very few problems.

(b) Most candidates failed to distinguish between angle of incidence and the angle between a wavefront and the normal. The diagram was usually completed but without reference to the answer obtained for the angle in (i).

HL only - Interference

(c) Candidates should appreciate that a necessary condition is not that the sources should have the same frequency – constant phase difference is the key issue.

(d) Effects produced by a change in wavelength were generally understood. However, it was apparent that few had any real understanding of what would be observed with white light.

Nature of light

(e) Many candidates did not express themselves clearly and concisely when recalling what is a standard piece of physics.

(f) A surprisingly large number of candidates failed to convert eV to joule before carrying out the calculation.

(g) (i) many stated that the current would increase, rather than double. In (ii), very few realised that the current would decrease. With an increase in photon energy, then the photon flux must decrease for constant intensity.

B2 (SL only)

Part 2 - Gases

(a) Apart from a failure to express the temperature in Kelvin, the calculation presented few problems.

(b) There were some correct solutions. However, a common error was to calculate the new amount of gas in the tyre and to divide this by the increase per stroke of the pump.

(c) Part (i) was completed successfully by the more-able candidates. Very few were able to calculate the efficiency as a result of confusion as to what energy should be shown in the numerator and in the denominator of the expression for efficiency.

(d) Candidates should appreciate that the term V in the ideal gas equation is the volume in which the atoms can move. If the atoms have a finite volume, then the term V should be reduced. Of those candidates who did attempt an answer, many thought that the term V should be increased.

B4 (HL only) Part 1 - Electricity

B3 (SL only)

(a) Most answers included a reference to free electrons in metals but failed to make a mention of positive charge.

HL only

(b) (i) Satisfactory answers were very rare. Most merely stated that the potential of Earth is zero, rather than discuss the fact that work must be done to bring a positive test charge from Earth to the sphere.

(ii) Again, few had any real understanding of the situation. The concept that any field would give rise to a force on, and hence movement of, electrons in the metal was not appreciated.

(iii) There were some good answers here. Some candidates thought that the electrons would pass from the student, rather than from Earth.

SL only

(b) (i) Few had any real understanding of the situation. The concept that any field would give rise to a force on, and hence movement of, electrons in the metal was not appreciated.

(ii) There were some good answers here. However, many candidates thought that the electrons would pass from the student, rather than from Earth.

HL and SL

(c) Many candidates produced mathematics so that they arrived at the given answers. However, explanation was lacking.

(d) Most candidates drew a circuit with a resistor in series with the device. In only a minority of scripts was there a genuine attempt to calculate the resistance.

(e) There were very few correct responses. There appeared to be many answers that were not based on physics principles.

Part 2 - Radioactivity

HL only

(a) (i) As is usual with the definition, there were many imprecise attempts. Candidates do not appear to appreciate the difference between isotopes, nuclides, nuclei and nucleons.

(ii) Decay constant was rarely defined in an adequate manner.

SL only

(a) As is usual with the definition, there were many imprecise attempts. Candidates do not appear to appreciate the difference between isotopes, nuclides, nuclei and nucleons.

HL and SL

(b) In general this was completed satisfactorily by the average and above-average ability candidates.

(c) (i) This was completed successfully by the majority of candidates.

(ii) This question did not involve a radioactive daughter product. Rather, candidates were expected to realise that the total number of nuclei would remain constant. This was apparent in a minority of scripts.

(d) There were very few successful attempts due, mainly, to a failure to appreciate what fraction of potassium would be remaining.

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. There were numerous instances where candidates lost marks as a result of a failure to follow the instruction to explain their working.

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 and the meanings of scientific terms. For example, the difference between a nucleus and a nucleon, the difference between proportionality and linearity. 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.

Higher and standard level paper 3

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-17	18-24	25-31	32-38	39-60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-8	9-11	12-16	17-20	21-25	26-40

General comments

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.

Candidates need to think about the action verb that starts a question. Action verbs such as "explain" "discuss" and "suggest" require that, for full credit to be given, a more detailed answer than that required by the action verb "state" is needed.

The majority of candidates showed the steps in calculations and so were able to gain credit by means of "error-carried-forward" marks.

Standard Level

The number of G2 responses was small. Of these:

- 61% found the paper to be of a similar standard to last year and 39% a little more difficult. However, overall, 93% found the paper to be of an appropriate standard and 7% thought it too difficult.
- 96 % found the syllabus coverage either satisfactory or good.
- 96% found the clarity of wording satisfactory or good.

- 96% found the presentation satisfactory or good.

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

Higher Level

- 58% found the paper to be of a similar standard to last year, 33% a little more difficult and 9% much easier. However, overall, 100% found the paper to be of an appropriate standard.
- 93% found the syllabus coverage either satisfactory or good.
- 93% found the clarity of wording satisfactory or good.
- 93% found the presentation satisfactory or good.

The areas of the programme that proved difficult for the candidates

As in previous years, a very prominent feature of this examination at both Standard and Higher Levels was 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:

- gravitational potential
- first law of thermodynamics
- sound intensity
- loudness
- luminosity
- apparent brightness

Many candidates had difficulty with the concept of moments and resolution of forces and with the concept of time dilation.
As mentioned above, many answers to certain types of questions, lacked detail or relied on anecdote rather than principles of physics.

Also, as in previous years, ray diagrams were often poor with candidates, it would seem, relying on memory rather than reasoned construct.

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 calculations through to the end. Routine calculations were also often done well in other areas with candidates usually taking care with significant digits and units.

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

SL only

Option A - Mechanics

Question 1 - Beam of wood

Candidates did not offer consider moments or resolution even though the components of the reaction force were given in the question.

Question 2 - Orbiting satellites

Only a handful of students referred to point masses or small mass in their definitions of gravitational potential.

A lot of "cooking" was seen in the deduction of the KE/PE relation but the calculation was often done well. However, in (c)(iii), answers to (b) and (c)(i) were not always used as was instructed in the question stem.

Question 3 - Projectile motion

An Energy argument was not often used to calculate the speed and the horizontal component of velocity was also often ignored. However, ECF marks were often awarded in part (b).

Option B - Atomic and nuclear physics extension

This was not a popular Option choice.

Question 1 - Energy levels and atomic models

There were some reasonable attempts at this question but all found the part of the Schrodinger model difficult.

Question 2 - Radioactive decay

The calculation in this question was found difficult by many candidates.

Option C - Energy extension

This was not a popular option choice.

Question 1 - First law and steam engine

This was not done well with candidates generally showing little depth in understanding of the first law. However, some candidates were successful with the calculation.

Question 2 - Solar power

There were some quite reasonable attempts at this question with most candidates able to gain at least some marks.

SL and HL combined

Option D - Biomedical physics

Question 1 - Scaling

Many of the candidates attempting this question were able to calculate the ratios correctly but were unable to apply them to answer the second part of the question.

Question 2 - Sound intensity levels.

Correct distinctions between sound intensity and loudness were rarely made and approaches to the calculation were often confused.

Question 3 - X-rays.

The non-mathematical sections were generally done well but the explanations of shadow image formation often lacked detail with very few candidates linking their answers back to their answers to part (c).

AHL

Question 4 - Forearm

This was often done quite well.

Question 5 - Dosimetry

The calculation proved difficult for a lot of candidates and was often left blank.

Option E - The history and development of physics

More candidates choose this option than in previous years.

Question 1 - Models of the Universe

Not many candidates could describe the observed motion of the Moon over a period of several years but the motion of Mars was well-known as was the Ptolemy model. The difference between Aristotle's and Newton's understanding of the motion of planets was also generally known well.

Question 2 - Force between charges.

This was not done well particularly the sub-question on how Coulomb determined the ratio of the charges on the two spheres.

Question 3 - Cathode rays.

Most answers demonstrated a lack of understanding of the topic addressed by this question. Many candidates confused the discovery of cathode rays with J. J. Thompson's measurement of e/m.

AHL

Question 4 - Spectrum and Bohr theory

This defeated many candidates with many not really knowing how to start.

Question 5 - Uncertainty principle

The idea that the momentum of the particle would be precisely defined but that its position would be indeterminate was rarely understood.

It has to be said that many candidates attempting this option relied on the core material for their marks.

Option F - Astrophysics

Question 1

Most candidates knew the position of the asteroids but few understand that the motion of Earth about the Sun results in the line of sight to some constellations being blocked at certain times of the year.

Question 2 - Stellar observation

Apparent brightness was often confused with apparent magnitude and the conversion to parsec was often missed in the calculation. The method of parallax was generally well known but some answers lacked detail in respect of defining the parallax angle.

Question 3 - Cosmology

Answers often lacked detail with such comments as "galaxies are red-shifted". Candidates need to appreciate that it is the spectral lines in the light from the galaxies that shows the red shift. The idea of an Earth-centred Universe is also common to many candidates as is demonstrated by such comments as "galaxies are moving away from us".
The sub-questions on critical density were often well done.

AHL

Question 4 - Hubble constant

Many candidates thought that it was difficult to measure H_0 because of the difficulty of determining velocities and did not recognise that accurate measurement of distance was the problem. However, the calculation was often done correctly.

Question 5 -Two different stars

The greater luminosity and higher temperature (though temperature was often missing) was stated correctly but the answer often stopped there. The rest of the question was often done well.

Option G - Special and general relativity

Question 1 - Relativistic kinematics and dynamics

Many candidates treated the first sub- question as a "state" rather than an "explain". The concept of frame of reference needs to be addressed for full marks.
Although the two postulates were generally well known, "in a vacuum" was often omitted.
There was much confusion as to which values to substitute for what in the velocity transformation equation, however, the rest of the calculation was often done well.

Question 2 - Muon decay and time dilation

This was generally not done well. The common misconception was that time goes slower if you move faster! Few candidates appear to appreciate the symmetry involved in the Special Theory; it would seem that many candidates are locked into the concept of an absolute frame of reference and seem to believe that there is a "stationary observer" for whom the physics is "correct". This would suggest that, even though some candidates are able to correctly state the postulates of relativity, they clearly have little or no understanding of their implication.
This lack of understanding was carried over into the phenomenon of muon decay. Such comments as "muons have a short half-life but when they move with a speed close to the speed of light, their half-life is extended and so they have enough time to reach the ground". Rarely was the Earth observer mentioned or the frame of reference of the muon mentioned or the symmetry of the situation appreciated.

AHL

Question 3 - Relativistic mechanics

There was a lot of "cooking" and a lot of references to $KE = ½\, mv^2$
The calculation was not done well even though the method is given in the question. As in previous years, candidates have difficulty with units expressed in terms of MeV.

Question 4 - General relativity

This was generally quite well done, however, in the calculation many candidates tried to work in wavelength and not frequency.

Option H - Optics

Although this is a very popular option choice, answers were often weak.

Question 1 - Dispersion and refractive index

This was generally quite well done but the "explain" parts of the question in (a) and in (b)(iii) were often not addressed.

Question 2 - Astronomical telescope

Definitions were often confused and ray diagrams were also often very poor with one of the rays incident on the eyepiece often shown going through the centre of the lens. Candidates were clearly relying on memory rather than understanding.
The effect of aberrations on the image of the object was not well understood; "blurred" was the usual answer.

AHL

Question 3 - Resolution

The sketches of the intensity distribution were often done well but a common error in the calculation was to regard the diameter of the aperture of the eye to be that of the diameter of Pluto.

Question 4 - Wedge film

Candidates often appreciated that interference was taking place but rarely associated the fringe system with the varying width of the air gap.
In the calculation, the diffraction equation was often used with $n = 1$ and θ determined from the fringe spacing indicating that the candidate was not appreciative of the situation.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team include the following:

- Candidates should not attempt to answer an option for which they have not been prepared.
- Definitions should be precise.
- Candidates should practice answering examination questions under examination conditions and also be assessed using the published markschemes.
- 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 each question carefully. Answers must be focussed – there is no need to write unnecessarily long sentences or give unnecessary information.
- Candidates should use the amount of marks allotted to a given part of a question and the number of lines available for the answer, as a 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 2×103 m nor can the distance of a star from Earth be 530 metres!
- 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.

