PHYSICS

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-27	28-39	40-49	50-59	60-70	71-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-28	29-39	40-50	51-61	62-72	73-100

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

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

Schools are providing balanced and thorough practical programs in physics. Although mechanics is traditionally the most popular topic many other areas are being covered, including the options as well as topics not in the syllabus. Standard investigations with worksheets need careful scrutiny before being assessed by the IA criteria. In most cases, such investigations are not appropriate for IA marking. Many schools are correctly recognizing error analysis including uncertainty bars on graphs. The majority of schools follow the administrative paper work requirements correctly and many schools are making use of the examples of investigations given on the OCC.

Candidate performance against each criterion

The Planning (a) criterion is often the most difficult for both students and teachers to appreciate. The best Planning (a) investigations are set before the students have covered any relevant theory. If you are investigating the period of a pendulum the students should not know or have access to the standard equation. Planning (a) investigation need to be open ended, and the best examples are where students look for a function or relationship, not a specific value or measurement. Determining the acceleration due to gravity, or the specific heat capacity of an unknown liquid, or to confirm Newton's first law, are not appropriate planning (a) investigations. Using standard lab equipment for an investigation is often penalized under Planning (b). There needs to be a variety of ways to investigating a topic. Often the Group 4 project is assessed under planning but it is difficult here for the moderator to know just what an individual student contributed. In general, it is best not to assess the planning criteria with the group project because students are working in teams. Data collection is normally well done. In physics, all raw data measurements have an uncertainty and this always needs to be indicated with the recorded data. When assessing data collection teachers must be careful not to tell the students what data to collect or how to record the data. Students must figure this out. Sketching water wave patterns or the pattern of iron filings due to a magnet does not count as data collection. Data must be quantitative. Data processing and presentation is usually well done. Often students are told what to do with their data, and this is not appropriate for assessment under DPP. The use of graphing software is encouraged but students must also demonstrate good graphing technique. Although more schools are including uncertainty bars on graphs, students must also justify the amount of uncertainty they record and not let the graphing program do it automatically. The number of significant digits must also be appreciated. The Conclusion and Evaluation assessment criterion is sometimes difficult for students. Conclusions must be based on a reasonable interpretation of the processed data and the original research question. Appreciating the scope and limit of an investigation is often difficult for students. Suggestions for improvement are often vague or general. Simply stating that a digital video would improve the quality of data is superficial and usually wrong. More critical thought is needed in each aspect of the CE criterion. When investigations are as good as they can be, then the conclusion and evaluation criterion should not be assessed for the given investigation.

Recommendations for the teaching of future candidates

- Teachers must always choose appropriate investigations to assess each criterion. Students and teachers should have copies of the IA criteria throughout the course. The use of worksheets or standard labs is often not appropriate for IA assessment.
- When teachers submit samples of IA for moderation, the verbal and written instructions for each moderated lab must be included.
- Group 4 projects are often the result of team effort and as such not appropriate for individual assessment under the IA criteria.
- The use of graphing software is encouraged but students must be in control of it and produce meaningful graphs.
- The syllabus content distinction between SL and HL under the handling of errors and uncertainties is important when assessing DPP.
- Continued use of the On Line Curriculum Centre is encouraged.

Schools have a good understanding of the IA requirements. Group 4 projects are interesting and students are enjoying the process. The influence of the OCC is noticeable, and the treatment of errors and uncertainties is generally good. IBCA research has shown that, even after moderation, the mean overall grade of students is higher with the IA than without.

Higher and standard level paper one

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 -10	11-13	14-17	18-21	22-24	25-28	29-40

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8-11	12-15	16-18	19-21	22-24	25-30

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, 16 for HL and 26 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 easier than last year, and the mean for both papers was indeed slightly higher. 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 and the clarity of the wording were either satisfactory or good.

Statistical analysis

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

The numbers in the columns A-D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank. The question key (correct option) is indicated by an asterisk (*). The *difficulty index* (perhaps better called 'facility index') is the percentage of candidates that gave the correct response (the key). A high index thus indicates an easy question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. A higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates.

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	109	141*	210	58	5	26.95	.37
2	347*	55	53	68		66.34	.37
3		232	5	286*		54.68	.35
4	24	64	371*	61	3	70.93	.44
5	85	200*	176	62		38.24	.35
6	47	320*	45	111		61.18	.45
7	74	45	163	237*	4	45.31	.51
8	9	347*	13	153	1	66.34	.26
9	55	115	251*	101	1	47.99	.42
10	299*	80	79	63	2	57.17	.37

11	15	16	138	352*	2	67.30	.36
12	49	356*	36	82		68.06	.43
13	21	73	181	246*	2	47.03	.04
14	34	297*	90	101	1	56.78	.26
15	132	63	286*	42		54.68	.55
16	113	9	33	367*	1	70.17	.48
17	98*	28	371	25	1	18.73	.28
18	366*	117	12	27	1	69.98	.29
19	70	69	345*	36	3	65.96	.52
20	10	12	447*	53	1	85.46	.17
21	188	119*	149	64	3	22.75	.39
22	31	301*	165	25	1	57.55	.30
23	168	37	201*	114	3	38.43	.25
24	422*	50	25	24	2	80.68	.24
25	30	212	241*	35	5	46.08	.31
26	72	209	123	115*	4	21.98	.20
27	203	183*	52	82	3	34.99	.28
28	70	46	55	349*	3	66.73	.54
29	343*	65	60	48	7	65.58	.55
30	25	57	307*	130	4	58.69	.51

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	132	209*	143	32	2	40.34	.37
2	315*	81	44	78		60.81	.28
3	269*	40	174	34	1	51.93	.56
4	68	270*	133	44	3	52.12	.55
5	37	384*	25	72		74.13	.34
6	51	33	106	319*	9	61.58	.46
7	11	347*	8	151	1	66.98	.23
8	59	70	322*	66	1	62.16	.47
9	89	41	98	281*	9	54.24	.56
10	4	28	478*	7	1	92.27	.13
11	43	33	19	423*		81.66	.35
12	21	169*	72	254	2	32.62	.07
13	27	368*	78	42	3	71.04	.27
14	50	32	213*	222	1	41.11	.44
15	73	125	159	160*	1	30.88	.32
16	172*	118	61	164	3	33.2	.19
17	146*	25	330	16	1	28.18	.47
18	424*	74	3	17		81.85	.24
19	387*	45	40	45	1	74.71	.42
20	63	31	393*	30	1	75.86	.33
21	180	119*	162	54	3	22.97	.28
22	21	274*	190	31	2	52.89	.30
23	358*	86	38	34	2	69.11	.42
24	52	108	33	324*	1	62.54	.36
25	271*	56	116	75		52.31	.46
26	343*	38	103	32	2	66.21	.47

27	29	197	267*	25		51.54	.40
28	57	183	110	164*	4	31.66	.39
29	44	234*	181	56	3	45.17	.36
30	180	271*	34	33		52.31	.42
31	316*	154	29	19		61.00	.41
32	107*	113	59	238	1	20.65	.30
33	66	53	201*	197	1	38.80	.30
34	406*	34	66	11	1	78.37	.35
35	177	107	210*	22	2	40.54	.30
36	51	117	96	250*	4	48.26	.52
37	142	286*	18	70	2	55.21	.41
38	122	220*	108	63	5	42.47	.47
39	50	113	243*	105	7	46.91	.53
40	95	273*	23	124	3	52.70	.39

Comments on the analysis

Difficulty

For both HL and SL, the difficulty index varies from approximately 20% to approximately 80% (relatively ‘easy’ questions) for all but two questions. 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. 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 vast majority of questions.

‘Blank’ response

In both Papers, there is a slight increase in the number of blank responses for the last few items. This may indicate that there were a few candidates who did not have sufficient time to complete their responses and there is evidence that some of the final questions were not read carefully. 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 Question 9 and HL Question 8

Many candidates did not distinguish between *speed* and *velocity*.

SL and HL Question 17

C was the most popular response, but the high discrimination factor indicated that the weaker candidates associated the average *speed* of the particles in a gas with the temperature, rather than the average *kinetic energy.*

SL and HL Question 21

The difficulty index for this question was low indicating that this topic requires greater emphasis. In particular the variation of amplitude within an internodal loop of a standing wave needs to be carefully considered.

SL Question 26 and HL Question 28

B was a very popular distractor amongst the weaker candidates. It cannot be assumed that all candidates will know that an electric current involves the relatively slow drift of electrons. The concept of drift speed should be given more emphasis.

SL questions

Question 1

Candidates are required to know the order of magnitude of quantities at an atomic level.

Question 3

There was evidence of a certain amount of guesswork between responses B and D, with the more able students identifying the key. It should be made clear that any zero before the first digit is not itself a significant figure.

Question 13

The statistics would indicate that many students are under the misconception that a body *momentarily* at rest is necessarily in equilibrium. This shows a fundamental confusion between velocity and acceleration and indicates that the consequences of Newton's Second Law need to be considered more carefully.

Question 14

It should be understood by candidates that *kinetic energy is conserved* is an alternative means of defining an elastic collision.

Question 16

It is recognised that there *may* be more than one phase present during all the regions of the graph, the only region where there *must* be more than one phase is XY.

Question 23

It is clearly stated in the syllabus that students need to know how to charge an object by induction. The evidence from the statistics would suggest that the candidates do not fully understand this process.

HL Questions

Question 3

Response C was being guessed by many of the weaker candidates, showing that they were not familiar with the use of logarithms in data analysis.
Teachers should note that the accepted convention is that *lg* is used for *logarithm to the base 10,* and *ln* for *logarithm to the base e*.

Question 12

It is important that the candidates appreciate the physical meaning of a minus sign in an expression. This will involve reading a question very carefully – in this case the work is being done *by the gravitational force*.

Question 14

Response D was more popular than the key although the discrimination was high for this question. This would indicate that weaker candidates are finding it difficult to solve ratio problems where there is more than one variable.

Question 15

This question had a high discrimination index, but there is evidence that the weaker candidates were guessing. The difference between *static* and *dynamic* friction should be given additional consideration.

Question 16

The discrimination index for this question was low showing that most candidates are not aware that, if a body is in equilibrium under the action of three forces, then the lines of action of these forces must all pass through the one point.

Question 29

C was a popular distractor amongst the weaker candidates showing that they automatically assume that a voltmeter has infinite resistance and do not see it as an integral part of the circuit it is monitoring.

Question 31

Candidates need to realise that equipotentials can be used to indicate changes in the magnitude of a field as well as its direction.

Question 32

This was a difficult question but the discrimination index was high. As with all questions, care should be taken when reading the stem – many candidates assumed R to be the magnetic flux density rather than the *rate of change of magnetic flux*.

Question 33

Despite the fact that *maximum* was in bold, many candidates chose response D indicating that they had not read the question carefully.

Question 35

The majority of candidates were not able to do this question, although it had a good discrimination index. This would suggest that the weaker candidates were on ‘automatic’ and had not read the question carefully enough to realise that the unit needed to be the *electron volt*.

Question 38

This was a difficult question for most candidates. They had perhaps not read the question carefully enough to realise that the photon was being *absorbed* and not *emitted*.

Higher and standard level paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-11	12-23	24-35	36-45	46-55	56-65	66-95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-18	19-24	25-29	30-35	36-50

General comments

The G2 forms suggested that the Standard Level paper was thought to be of a similar standard to those in previous years, but a few teachers did think that the Higher Level paper was a bit easier. Most teachers thought that the syllabus coverage, clarity of wording and presentation were either satisfactory or good.

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

- Candidates did not pay sufficient attention to the action verbs described in the syllabus guide.
- Candidates had difficulty dealing with resolution of forces and using trigonometry to solve equilibrium mechanics problems.
- Candidates were careless in their drawings of field lines and equipotentials.
- Candidates had difficulty with definitions in general and in particular with those involving gravitation and electric fields and potentials. This is, however, 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. Their answers frequently lack precision and are expressed in non-scientific language. A thorough knowledge of such definitions is essential since they provide a basis for an understanding of the concepts that they define and thus, do need to be precise.
- Candidates should also realise that the final numerical answer to a calculation must be given to the number of significant digits consistent with the given data. There was some improvement in this area in this examination.
- Candidates should also be encouraged to clearly outline the methods 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

There were some very good answers to questions on Mechanics, Electricity and Waves. Omission of units and errors with significant digits seemed to be less of a problem than in previous years.

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

Section A

A1 (HL and SL)

Data Analysis.

a) This was well done by the great majority of candidates. A few were misled into drawing a curve appropriate to an inverse square law, presumably because they failed to notice that the variable on the x-axis was not *r*.

b) (i) This part was also generally well done with the majority of candidates drawing a straight line not passing through the origin. It was pleasing to note that most were using a ruler when drawing the straight line.

(ii) Many candidates gave general descriptions of random and systematic errors without relating them to the graph in question.

(iii) The great majority of candidates could identify a reasonably large triangle with which to calculate the slope but most did miss the powers-of-ten on the axes, with the result that an incorrect slope was calculated.

(iv) There were errors here with q^2 being replaced by $2q$. However, very many candidates managed to relate the slope to kq^2.

c) **HL only** Many candidates did not correctly apply logs to the equation in order to show that the value of the exponent of *r* is obtained from the gradient. It must be noted that the symbol "lg" is the standard symbol for a logarithm to the base 10 just as "ln" is the logarithm to the base e.

A2 (HL and SL)

Balloon taking off

a) It has been an enormous surprise to see so many candidates failing to realize that the net force on the stationary balloon would be zero.

b) This part was also poorly done, pointing to the need for better practice with mechanics problems that require resolution of forces. There were many confused answers mixing up sines and cosines of various angles.

c) Most candidates could score some marks here as a result of error-carried-forward, but very few could actually substitute the correct value of the accelerating force.

d) This part was generally well done, with most candidates stating that the frictional force would increase.

A3 (SL only)

Electric fields

The definition of electric field once again proved difficult for most candidates. The drawing of the electric field lines was generally well done but many candidates showed lack of care with their diagrams.

A3 (HL only)

Binding energy

a) This simple definition proved beyond many candidates who resorted to very vague statements such as “particles in a nucleus”.

b) The precise definition of binding energy was seen rarely.. There were many vague and unacceptable statements such as “the energy needed to hold a nucleus together”.

c) Many candidates could identify the regions where fusion or fission take place but few could correctly explain why energy is released by pointing to the higher binding energy of the products. It should be made clear that it is the binding energy, not the binding energy per nucleon, that is the determining factor.

d) This part was well done by very many candidates. A few missed the neutrino in (i). A good number of candidates managed to obtain the correct answer to part (ii) without actually using moles. Many calculated the mass of the nucleus by adding the masses of the protons and the neutrons – this was a tedious method, but gave them the answer. In part (iii) it was clear that many candidates still do not know that the initial activity of a sample is given by λN_0. This should be a straightforward application of simple differentiation with which candidates should be familiar (and, incidentally, an interesting application of calculus in Physics).

Section B

B1

Part 1 (HL and SL)

Electric circuit

a) This was well done by most.

b) In (i), many candidates identified the high resistance of the voltmeter as the reason the lamp would not light but few could take the extra step and deduce that the current in the circuit would be close to zero. Similarly in (ii) many could correctly state that the reading of the voltmeter would be 3.0 V but few could explain why.

c) A disappointingly large number of candidates could not place the meters correctly in the circuit. It is clear that the potential divider circuit is still causing problems for many candidates.

d) Many did this correctly with a reasonable proportion drawing a straight line.

e) Most referred to non-ohmic behaviour but few mentioned the increase of resistance due to an increase in temperature.

Part 2 (HL and SL B2 Part 1)

The physics of cooling

a) Many of the definitions given included correct phrases but not always in a coherent and logical order. Temperature is proportional to, or is a measure of, the average kinetic energy of the molecules of the substance but it *is not* the average kinetic energy of the molecules. In fact the word “molecule” seldom appeared in candidates’ answers.

b) Very many continued the graph with a straight line whereas a curve was required. Candidates must note that the word “line” does not necessarily mean “straight” line.

c) The question was based on the fact that in both (i) and (ii), there was thermal energy loss from the substance. In (i) the rate of thermal energy loss was large due to a large temperature difference between the substance and the surroundings. In (ii) there was a phase change taking place, with thermal energy loss despite a constant temperature. Most answers lacked sufficient detail here.

d) This was generally well done with many candidates calculating an acceptable value for the temperature gradient, even if occasionally the average rather than the instantaneous gradient was obtained.

B2 (HL only)

Part 1 Fields and potential

a) The definition of electric potential once again proved difficult. The concept of the ratio of work to charge was omitted, as was the fact that the definition involves a positive test charge.

b) (i) Perfect circles were not expected but a little more care in drawings is necessary. In some cases, the "circle" was indistinguishable from an ellipse and in others, the circles were open, not because the candidates intended their drawings to be so but because they had not taken sufficient care. In (ii) many failed to realise that the curve had to pass though the point (0.5, 3) since they were plotting an $\frac{1}{r+R}$ graph. Some, despite the bold face print, did not pay attention to the fact that the distance was to be measured from the surface of the sphere. A few candidates seemed to know that electric field is related to the gradient of the potential but few could actually say precisely at what point the gradient had to be evaluated.

c) Generally well done.

d) Generally well done.

e) Generally well done.

f) Generally well done.

g) Answers here were vague ad, frequently, candidates fell into the trap of saying that the astronaut is so far away that the gravitational force on him/her is negligible. Many correctly identified the satellite and the astronaut as both being in free fall but did not conclude that any reaction force betweenh the satellite and the astronaut must be zero.

h) Most realised that both vary as $\frac{1}{r}$ but few went further to say that the gravitational potential increases whereas the electric potential decreases with increasing distance.

Part 2 (HL only)

Expansion of a gas

This question was generally well done. Most could calculate the pressure in (a) and many realised that the work done was represented by the area under the graph. A few thought that the area to be included was the triangular section only, and not the complete area as far as the volume axis. The graph showing the variation of pressure with volume was not drawn well by most. The only difficult part of this question was the explanation of why less work would be done in an adiabatic expansion. Very few candidates could use the fact the adiabatic curve leaving the initial point would be steeper than the corresponding isotherm, hence enclosing less area. Many used the first law of thermodynamics but without success. Others just defined what is meant by an adiabatic process when, clearly, this was not what was required.

B2 (SL only)

Part 2

Parts (a) – (c) are common with A3 (HL) parts (a) – (c).

Most candidates were able to answer the remaining parts - (d) and (e) - quite satisfactorily.

B3

Part 1 (SL and HL)

Standing waves

This proved to be an extremely unpopular question at both SL and HL.

a) Generally well done but many candidates were unclear about the amplitude within an internodal loop being variable for a standing wave.

b) This was very well done, apart from (iii) where candidates had great difficulty explaining their answers clearly..

(HL only)

De Broglie waves and the hydrogen atom

The rest of the question resulted in very poor responses.

c) In (i), students were very vague in describing de Broglie waves and very few made reference to probability. Most could correctly derive the formula for the wavelength in (ii) but rarely could anyone describe an experiment in support of the de Broglie hypothesis. There were all many experiments mentioned here, including X-rays production, Young's two-slit experiment and the photoelectric effect. Of those who did manage to refer to an electron diffraction experiment, many could not conclude their discussion with the statement that the experiment actually measures a wavelength for the electron that is in agreement with the de Broglie formula.

d) Most answers were acceptable.

e) Frequently, answers were confused and contradictory. Some credit could be awarded as a result of error-carried-forward. Most failed to use conservation of energy in their answers.

Part 2 (SL only)

Linear momentum

a) Many candidates could define momentum and impulse correctly.

b) Most knew that both quantities are vectors but few could explain why by, for example, pointing to the vector nature of velocity.

c) Answers here were either excellent (from more able candidates who had obviously practiced this before) or very poor. It was clear that very many candidates never attempted to read what is a standard proof in practically every available textbook. Very many candidates did not appreciate the relevance of Newton's third law in the 'derivation' of momentum conservation.

d) In part (i), many candidates made the very common mistake of forgetting the sign in front of momentum and, consequently, arrived at an incorrect answer. However, error-carried-forward allowed them to be given credit in part (ii). In part (iii), many answers were based on the assumption that the steel ball would exert a greater force (which is of course precisely what the question stated). Few could give a reason for this increased force by, for example, identifying a shorter contact time.

B4 (HL only)

Part 1

Properties of sound waves

a) This was done well by the majority of candidates. A common error was to fail to divide by a factor of 2 since the wave covers double the depth in the given time. A few did not convert milliseconds to seconds before calculating the distance.

b) There were varied answers here. As in other questions, the diagrams lacked care and attention to detail. Many seemed to indicate correct ideas but diagrams did not convey the intended meaning. Frequently, the separation of wavefronts was not shown to be constant even though, undoubtedly, candidates did not believe that the wavelength changed. The geometric shadow region immediately behind the obstacle was not shown clearly and in many instances the wavefronts behind the obstacle were shown overlapping. In part (ii), most realised that the wavelength of the sound wave of frequency 60 kHz would be short, but they did not relate this to the length of a typical large fish in order to claim that diffraction would be negligible.

c) Definitions of the Doppler effect were not clear and many simply resorted to examples of the effect such as police sirens on highways. Few could point to an apparent change in the source's frequency due to relative motion between source and observer. Many answered in terms of a change of wavelength, which is incorrect as wavelength does not always change. Part (ii) was a typical Doppler effect calculation. Despite this, very few candidates arrived at the correct answer. The great majority of candidates wrote down the Doppler formula (with both signs) and could get no further. There was a great range of speeds obtained! The question asked for an estimate and therefore it was legitimate to assume that the source frequency would be the average of 410 Hz and 490 Hz i.e. 450 Hz. The few who used this frequency did not, however, provide any justification. The correct procedure for solving the problem is to set up two equations – one as the source approaches and another as it moves away - and then take a ratio.

Part 2 (HL and SL B1 Part 2)

Kinematics

a) This was well done by most, even though many used terms such as "closed systems" or "isolated systems" without caring to define what was meant by these terms.

b) Very few could point to chemical energy in the plane's fuel as the source of energy for the plane. Many answers just said that the plane gained kinetic energy. Candidates should discuss transformations of energy at an appropriate academic level.

c) No comment.

d) A small fraction of students thought that the direction of the resultant force on the plane would be away from the centre of the circular path.

(HL only)

e) This was reasonably well done, using equations of kinematics or energy conservation. However, many did fail to calculation the angle. In part (ii), only a small proportion of the candidates could correctly predict that air resistance would make the velocity vector more vertical. Initially, the vertical speed is small and will increase to a constant value. The horizontal component will reduce to zero.

Recommendations and guidance for the teaching of 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 is not rewarded.

General comments and non-scientific language are unacceptable when defining quantities and terms. Definitions, by their very nature, are precise. Students must be encouraged to simply memorize the essential definitions appearing in this syllabus. Candidates should be encouraged to develop a thorough knowledge of standard results, explanations, derivations and descriptions of phenomena.

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 ms rather than s).

When using data from a graph, candidates must make sure that they check for the units on the axes. Often a given quantity, for example volume, is plotted in units of $10^{-3}\,\mathrm{m}^3$ and the power of 10 must be taken into account in any subsequent calculation.

Where diagrams and graphs are drawn, these should show the relevant important features e.g. spacing of wavefronts or straight lines. In drawing field lines around a charged sphere for example, the lines must be shown evenly spaced and at right angles to the sphere. A ruler must be used whenever a straight line expected. 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 three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-19	20-25	26-32	33-38	39-60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-8	9-12	13-16	17-21	22-25	26-40

General comments

Examiners found that, in general, candidates did not score as highly as in November 2004. This was due partly to fewer very capable students. However, there were further more disturbing elements. Some questions involved parts of the syllabus that had not been tested previously. Clearly, candidates were not prepared for such questions and had been lulled into believing that it is sufficient to study only the contents of past papers. In each Option, there were parts of questions that can be described as the testing of knowledge. It was disappointing to observe that many candidates failed to score a significant number of marks for what can only be described as straight-forward physics.

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 several 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

- 64% of G2's indicated that the paper is of a similar standard to last year, 18% a little easier and 18% a little more difficult. However, overall, 71% found the paper to be of an appropriate standard but 29% thought it too difficult.
- 91% 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

- 82% found the paper to be of a similar standard to last year and 18% a little more difficult. However, overall, 87% found the paper to be of an appropriate standard and only 13% thought it to be too difficult
- 100% found the syllabus coverage either satisfactory or good.
- 93% 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).

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

- Avery 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 plainly incorrect.
- As in past examinations, many candidates displayed weakness in the drawing of ray diagrams. Candidates should be encouraged to use a straight edge when drawing rays.

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

The general impression gained by examiners was that there were no areas where excelled. Candidates appeared not to be well-prepared `and to have spent insufficient time studying the Options so as to gain an understanding of the underlying concepts.

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

SL only

Option A – Mechanics Extension

Question 1 Projectile motion

In (a), there were some correct responses. However, it was common to find that candidates thought there would be an acceleration in the horizontal direction or to give the unit of acceleration as m s^{-1}. Parts (b) and (c) were generally well done, with candidates substituting numbers into familiar formulae.

Question 2 Gravitation

In (a), many candidates were unable to give anything resembling a correct definition. Frequently, work done per unit mass was not included. There were very few who mentioned moving the mass from infinity to the point. Consequently, answers in (a)(ii) seldom scored any credit. Candidates should appreciate that negative values are a consequence of the force between masses being attractive in nature. In (b), there were some good answers, based on finding the values of the field strength at P due to the individual masses. Some candidates found only one value and then merely stated that the value is small. Those candidates who equated kinetic energy to gravitational potential energy had little difficulty in (b)(ii). However, many attempted to use the formula for the escape speed from the surface of an isolated planet.

Question 3 Equilibrium

It was common to find that the direction of the force at P due to the rod was reversed in direction or was not along the rod. Consequently, in (b), there was widespread confusion. Candidates should be encouraged to solve such problems by resolving in two directions at right-angles to one another. Instead, many wrote down some form of a single equation that was not explained and was incorrect.

Option B - Atomic and nuclear physics extension

Question 1 Wave-particle duality

Most answers made reference to the relevant equation, but frequently, symbols were not explained and verbal explanation was lacking. In the calculation, a common problem was associated with determining momentum from kinetic energy. Some candidates substituted kinetic energy, rather than momentum, into the relevant formula.

Question 2

Candidates were asked to describe *how the spectrum may be obtained*, for example, the use of a diffraction grating or a prism. In many answers, candidates had not read the question and described the energy changes associated with a line spectrum. In (b), there were some very good answers. On the other hand, despite being given the photon energy, in (c) many could not identify the energy level associated with this change.

Question 3 Radioactive decay

Most answers indicated that candidates realised that they had to use curve R in (a). Most gave the correct numerical value for the decay constant but it was very common to find that no unit was quoted. In (b), very few candidates realised that, at the maximum, the rate of formation of the daughter D would be equal to its rate of decay. Part (c), involved the interpretation of the graphs. However, very few recognised that S and D change very slowly with time at the suggested age.

Question 4 Neutron decay

The question tested knowledge in the context of neutron decay. Some candidates had, quite clearly, simulated the necessary knowledge and consequently, scored full marks. Others had, evidently not studied the subject.

Option C - Energy extension

Question 1 Ideal gas

Part (a) should have been very straight-forward. However, it was clear from the answers given that candidates had not learned the proof, as stated in the syllabus. Such questions should provide easy marks. In (b), there were some very competent answers. On the contrary, many candidates had little or no appreciation of the situation.

Question 2 Carnot cycle

Although most answers were adequate as regards a statement of what is meant by an adiabatic change, very few could describe, how, in practice such a change is achieved. Part (b) was usually answered correctly. In (c), there was the usual confusion between the Celsius and kelvin scales. In (d), candidates should realise that at this level, it is insufficient to merely quote 'friction'. For example the location of the frictional forces should be made clear.

Question 3 Wind turbine

For those who had studied carefully this Option, then part (a) provided easy marks. However, many answers indicated a total lack of understanding of the situation. In (b), a common error was to treat the length of one blade as the diameter, rather than the radius, of the area *A*. However, there were some correct answers. Weaker candidates frequently ignored the energy of the air after it had passed through the turbine.

SL and HL combined

Option D - Biomedical physics

Question 1 Shape and form

Many candidates had, apparently, practised on questions involving scaling. Consequently, despite being told that the question relates to shape and form, they attempted an answer in terms of scaling. There was a minority where reference was made to wing shape. There was a clear realisation that shape does affect lift and drag at high and low speeds.

Question 2 The ear

Candidates were guided through parts (a) and (b), and many scored high marks. However, very few could interpret the equation in (b)(ii) to reach any conclusion as regards the function of the ossicles. Most thought that the ossicles merely 'transmitted vibrations'.

Question 3 X-rays

In (a), the lack of precision and detail was particularly evident when sketching the graph. Many candidates were able to quote a relevant formula but far fewer explained the symbols satisfactorily. Definitions of half-value thickness frequently lacked precision. A reference to intensity, rather then merely stating 'reduce the X-ray beam by one half' is necessary. Answers in (b) seldom scored full marks since reference was not made to attenuation coefficients, as expected in the question. The difference between the coefficients should have been included, leading to an explanation as to why the *outline* of the organ would be made clear.

AHL

Question 4 Human arm

Most candidates could give an adequate definition of centre of gravity. However, a significant number did not show G anywhere near the centre point of AB. There were some satisfactory answers in (c), but weaker candidates failed to realise that the turning effect of forces has to be considered.

Explanation of the calculation in (d) was frequently inadequate or totally omitted. Candidates should realise that explanation is important, particularly where the final answer is incorrect. It is only as a result of such explanation that marks can be awarded for correct procedures. There were some good suggestions made in (e) as regards the relative distances that would be moved by the load and by the effort.

Question 5 Radiation damage

Answers were disappointing in that most concentrated on the effects of radiation damage, that is, inducing of cancers etc. Candidates were expected to include ionisation and how ionisation can have direct and indirect effects on large vital molecules in cells.

Option E – The history and development of physics

Question 1 Retrograde motion

Most answers included a diagram of the path but frequently, this was unlabelled. Consequently, the diagrams had little meaning. Explanations in (b) and (c) were usually adequate.

Question 2 Caloric theory

In part (a), section (i) was usually explained well in terms of movement from high to low temperatures. However, in (ii), very few could give the explanation for latent heat in terms of combining with particles and thus becoming inactive in raising temperature. Part (b) presented very few problems.

Question 3 Electricity and magnetism

Candidates could be divided into two groups. First, those who had learned the work and, in general, scored well. The second group scored very low marks and, from the answers, had not studied the subject at anything like an appropriate level.

AHL

Question 4 Quantum concepts

In (a) and (b), many seemed to understand the general principles involved but failed to include the appropriate detail in the descriptions. Generally, questions allocated three marks cannot be answered adequately with a one-sentence response.

Option F – Astrophysics

Question 1 Solar system

Part (a) presented very few problems. However, in (b), many did not distinguish between the planets themselves and their orbits. In (c), many candidates lost marks through not reading the question. They described features of a comet, rather than the orbit.

Question 2 Stellar spectra

This was another question where well-prepared candidates scored high marks. Disappointingly, there were many low scores.

Question 3 Stellar magnitude and brightness

Parts (a) and (b) should have presented very few problems. However, a significant number could not give adequate definitions, based on standard textbook knowledge. In (c), weaker candidates did little more than paraphrase the question. They were expected to start by stating that an apparent magnitude 1 is 100 times brighter than apparent magnitude 6 and to derive the factor of 2.5.

In (d), some quoted an expression relating apparent and absolute magnitude. They were, of course, awarded full credit for a correct answer. However, candidates could calculate the change in magnitude as a result of moving from a distance of 14 pc to 10 pc. Hence the absolute magnitude.

AHL

Question 4 Stars

As for question 2, well-prepared candidates benefited from this straight-forward question.

Question 5 Extragalactic astrophysics

Parts (a) and (b) were generally well answered. However, candidates should be encouraged to explain symbols whenever they quote a formula. Part (c) was disappointing. Rather than discuss why the technique is not applicable, most preferred to briefly mention an appropriate technique.

Option G - Relativity

Question 1 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 is constant. Many also forgot to specify that the frames of reference involved are all inertial.
In (c), most could identify correctly the appropriate change. However, candidates tended to state, without explanation , what change they expected to find in the density.

Question 2 Muon decay

This familiar question, set in a slightly different context, was completed successfully by well-prepared candidates. Others appeared to have little appreciation of basic concepts. In (c), explanations were frequently marred by paraphrasing the question. It is of little value to state that ‘time dilation is a dilation of the time……..’.

Question 3 Relative velocity

Marks were awarded for the correct substitution into the relevant formula, as well as for the answer. Weaker candidates who did not arrive at the answer benefited from adequate explanation of what they were doing.

AHL

Question 4 General relativity

Answers were frequently of a high quality and it was evident that candidates had studied the relevant bookwork. However, there was a small number of scripts where candidates had little or no idea of the situation.

Question 5 Relativistic momentum and energy

Most candidates quoted correctly a relevant formula. However, few succeeded in arriving at the correct answer. Use of the units MeV and MeV c^{-1} gave rise to much confusion, with some attempting to convert to J and to Ns.

Option H – Optics

Question 1 Electromagnetic waves

In (a), there was an error in translation from English into Spanish. ‘the electromagnetic nature’ was translated as ‘the wave nature’. The marking scheme was modified accordingly to accommodate both approaches. In (b), many answers revolved around the idea that wavelength would be ‘small’ or frequency would be ‘high’. Very few mentioned that frequency is independent of the medium through which the wave is travelling.

Question 2 Refractive index

As is always the case where candidates are asked to draw standard ray diagrams, most attempts were of no real value. Such diagrams should cause minimal problems. In (b), a distance was calculated but many did not make it clear as to whether this calculated distance is from the top surface or from the bottom of the block. Very few correct answers were given to (c). If the proof of the expression for real/apparent depth had been studied, then candidates should realise that it is assumed tanθ to be equal to sinθ and this is true only for small angles.

Question 3

Parts (a) and (b)(i) presented very little difficulty. However, the calculation in (b)(ii) was completed successfully by very few candidates. The lenses act as a lens combination and the real image produced by the convex lens acts as a virtual object for the concave lens. Thus, the signs in the lens formula can be established. The majority of candidates failed to realise that the second lens is concave. In (d), many did realise that the separation of the lenses is important. However, there was confusion as to whether increased separation would increase or decrease the focal length of the combination.

AHL

Question 4 Rayleigh criterion

Many candidates had some idea of the Rayleigh criterion but their answers often lack precision. It was common to find that reference was being made to the objects overlapping, rather than the diffraction patterns.
Part (b) asked candidates to estimate the distance between two sources. Many used the equation $\theta \approx 1.22\frac{\lambda}{b}$ and attempted to equate this to some other angle. However, there was considerable confusion as to what distances to substitute into the formulae.

Question 5 Interference

In (a), there appeared to be much guesswork on the part of many candidates. This became evident in (b). It was surprising how few correct responses were seen for such a straightforward calculation.

Recommendations and guidance for the teaching of future candidates

Recommendations from the examination team included the following ideas:

- Candidates should study the whole of each relevant Option and should be prepared to answer questions on any part of that Option. Past Papers should be used to indicate the depth of knowledge and understanding required. They do not indicate what subject material may, or may not, be examined.

- Candidates should be encouraged to develop a sound knowledge of the fundamental principles. It is only then that they can expect to develop an understanding of underlying concepts.

- 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 give some indication 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 through the question paper before starting, not only to gauge the variety of questions but also the number of sections in each question and the level of difficulty.
- 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 number 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.

