PHYSICS (IBAP & IBAEM)

Overall grade boundaries

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-26	27-37	38-48	49-58	59-69	70-100

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-27	28-38	39-49	50-59	60-70	71-100

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

Internal assessment

Component grade boundaries

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

The range and suitability of work submitted

The majority of schools are providing balanced and thorough practical programs in high school physics. Although mechanics is traditionally the most popular topic many other areas are being covered, including the options. Some difficulties arise in the suitability of investigations for assessment when schools teach two or more academic programs together. When an experiment is appropriate for one curriculum it may not be appropriate for the group 4 IA criteria. The teachers need to pay close attention to this issue. Standard investigations with worksheets need careful scrutiny before assessing these using the IA criteria. Many schools are correctly recognizing error analysis with uncertainty bars on graphs. This has improved over previous years. Overall, most school follow the administrative paper work requirements correctly. Many schools are following the examples of investigations given on the OCC.

Candidate performance against each criterion

The two planning criteria remain the most difficult for both students and teachers. The best planning (a) investigations are set before the students have covered the relevant theory. Planning (a) investigations 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 investigate 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 group project because students are working in teams.

Data collection is often very well done. Students are more than ever aware of uncertainties. In physics, all raw data measurements have an uncertainty and this 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 when they are assessed under data collection. Sketching water wave patterns or the pattern of iron filing due to a magnet does not count as data collection.

Data processing and presentation is not done as well as it should be. 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 be appreciated. Often a systematic shift in the best straight line is not accounted for.

The conclusion and evaluation assessment criterion is also 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.

Recommendations for the teaching of future candidates

- Teachers must choose appropriate investigations to assess each criterion. Students and teachers must have copies of the IA criteria. 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 IB encourages the use of graphing software 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 Online Curriculum Centre is encouraged.

Further comments

The overall trend shows a noticeable improvement in the administration and in the assessment of practical work. The influence of the OCC is noticeable, and the treatment of errors and uncertainties has improved.

Paper 1

Component grade boundaries

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-14	15-17	18-20	21-23	24-29

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-14	15-18	19-22	23-27	28-31	32-40

General comments

IB multiple choice physics papers are designed to have, in the main, questions testing knowledge of facts, concepts and terminology and the application of the aforementioned. Although the questions may involve simple calculations, calculations can be assessed more appropriately in questions on Papers 2 and 3. Calculators are therefore neither needed nor allowed for Paper 1. A proportion of questions are common to the SL and HL papers, with the additional questions in HL providing further syllabus coverage. The number of questions dedicated to each topic is proportional to the number of teaching hours proposed for each topic in the Guide. However, it is not possible to reflect all aspects of each topic considering the limited number of questions available for the SL and HL papers.

The number of G2's received was 72 for HL and also 72 for SL. The replies indicated that the May 2005 papers were generally well received. Approximately 90% (at HL) and 94% (at SL) of the teachers who commented on the Papers felt that they contained questions of an appropriate level with a small number thinking they were either too difficult or too easy. With few exceptions, teachers thought that the Papers gave satisfactory or good coverage of the syllabus (94% at HL and 96% at SL). However, it should be borne in mind that overall coverage must be judged in conjunction with Paper 2. All teachers also felt that the presentation of the Papers was either satisfactory or good.

Statistical analysis

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

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

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	376	1046*	380	361	10	48.13	.39
2	189	3578	107	1514*	6	69.67	.36
3	982	-	779*	410	2	35.84	.08-
4	267	151	1612*	142	1	74.18	.39
5	994*	659	497	22	1	45.74	.60
6	1210*	271	647	44	1	55.68	.45
7	457	619*	532	563	2	28.48	.40
8	298	1087*	595	188	5	50.02	.35
9	194	542	1275*	161	1	58.67	.53
10	1537*	165	466	-	5	70.73	.20
11	466	294	273	1133*	7	52.13	.33
12	90	85	28	1967*	3	90.52	.16
13	170	1795*	197	10	1	82.60	.30
14	214	51	1797*	107	4	82.69	.30
15	125	260	613	1174*	1	54.02	.27
16	71	897	732	469*	4	21.58	.37
17	45	191	1337*	187	3	61.52	.39
18	583	686*	568	334	2	31.56	.50
19	830	135	1158*	46	4	53.29	.40
20	483*	462	1051	169	8	22.22	.17
21	754	225	1030*	156	8	47.39	.28
22							
23	395	666	664*	433	15	30.55	.19
24	795*	586	239	545	8	36.58	.46
25	110	1248*	697	109	9	57.43	.42
26	89	311	261	1505*	7	69.25	.51
27	427	131	86	1521*	8	69.99	.43
28	248	93	1760*	68	4	80.99	.39
29	1851*	103	106	109	4	85.18	.34
30	251	1138	484	290	10	52.36	.57

In Q3 above, B and C were both marked correct and in Q10, A and D were both marked correct.

Q22 was not included in the test.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	375	1463*	467	376	8	54.40	.36
2	1283		851*	553	2	31.64	.14-
3	139	145	2248*	154	3	83.59	.24
4	202	742	1598*	143	4	59.42	.52
5	1770*	402	511	5	1	65.82	.53
6	303	1763*	412	208	3	65.56	.33
7	1930*	224	524		11	71.77	.27
8	473	245	226	1743*	2	64.81	.25
9	1751*	99	191	645	3	65.11	.42

10	45	1177*	322	1139	6	43.77	.56
11	256	56	2210*	164	3	82.18	.18
12	119	545	1823*	197	5	67.79	.49
13	302	1440*	512	426	9	53.55	.50
14	71	179	666	1770*	3	65.82	.27
15	57	856	676	1098*	2	40.83	.54
16	1618*	128	862	79	2	60.17	.25
17	2203*	122	59	304	1	81.92	.29
18	662	72	1922*	30	3	71.47	.40
19	1080*	459	1066	80	4	40.16	.43
20	172	1274*	729	506	8	47.37	.37
21	1011	1424*	164	88	2	52.95	.41
22	1093	971	83	541	1	36.11	.26
23	133	825	112	1615*	4	60.05	.29
24	122	269	1889*	395	14	70.24	.33
25	332	591	1198*	557	11	44.55	.33
26	1414*	708	193	369	5	52.58	.51
27	46	151	197	2292*	3	85.23	.28
28	150	316	318	189*	9	70.50	.51
29	306	190	1829	355	9	68.01	.40
30	1430*	519	383	348	9	53.17	.56
31	1105*	427	981	166	10	41.09	.60
32	81	56	2482	63	7	92.30	.15
33	396	491	297	1498*	7	55.70	.57
34	1603	391	371	311	13	59.61	.53
35	291	424	380	1586*	8	58.98	.54
36	253	1673*	369	381	13	62.21	.43
37	333	322	671	1354*	9	50.35	.40
38	179	836*	787	878	9	31.08	.42
39	705*	254	1230	486	14	26.21	.36
40	753	493	354	1076*	13	40.01	.51

In Q2 above, both B and C were marked correct and in Q7, A and D were both marked correct.

Comments on the analysis

Difficulty. For both HL and SL the difficulty index varies from around 20% (relatively 'difficult' questions) to greater than 90% (relatively 'easy' questions).

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

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

Comments on selected questions

Candidate performance on the individual questions is provided in the statistical tables above, along with the values of the indices. For most questions, this alone will provide sufficient feedback information when looking at a specific question. Therefore comment will only be given on selected questions, i.e. those that illustrate a particular issue or where a problem can be identified.
Some easy questions were deliberately chosen and other more demanding questions were designed to discriminate between students with good knowledge and skills. The statistics of both papers show a list of very good discrimination indices.

SL and HL common questions

SL Q3 and HL Q2
The diagram in the question paper distributed to candidates leads to some doubt as to whether the Key should be B or C. Consequently, it was decided to allow both B and C as keys.
The context of the question, a thermometer, is not relevant *per se* since the question is about reading a scale. The size and clarity of the scale (with a large "gap" for each division) is such that answers A and D are not acceptable here. The rule of thumb ±1/2 division is not satisfactory in this context.

SL Q10 and HL Q7
Both A and D were allowed as keys.

SL questions

Q2
The relevant information does appear in the Data Booklet. However, on statistical grounds, the item can be justified. The item has a high discrimination index. The Data Booklet is available to all candidates and therefore no particular group was advantaged or disadvantaged.
Q6
The distractor C illustrates a common misconception.
The item has a very high discrimination index, indicating a common error that has also been apparent in Paper 2. Namely, weaker candidates consider speed as being only the positive gradient of an *s/t* graph.

Q7
It would have been preferable to use the word "decreasing" rather than "diminishing" but the statistics indicate that students were not unduly affected by this choice of words. The majority of more-able candidates chose the key whilst others the others resorted to guesswork.

Q13
The high level of success shows evidence of well-trained candidates.

Q15
The choice of Options B or C demonstrate popular misconceptions.
One advantage of multiple choice items is that the level of understanding of candidates as regards definitions may be tested easily.

Q22
A number of teachers indicated that the second line of the stem could suggest that the rod touches the plate. This ambiguity does not exist in the French or Spanish version of the Paper. However, it was decided that the item should be eliminated from the test.
The wording is improved in the final published version of the question papers.

Q23
It would appear that many candidates failed to allow for the fact that the charge of an α-particle is +2*e*, not +1*e*.

HL Questions

Q6
In the version of the question paper given to candidates, the vector N was not defined in the stem of the item. Reference to the statistics would indicate that candidates were not affected adversely.

Q10
The distractor D was a very popular choice. Possibly, candidates did not read the question carefully.
Since gravitational field strength is force per unit mass, then any expression for force must be incorrect.

Q21
As in item 10, it would appear that many candidates did not read the stem carefully.
Candidates should be advised that, in physics papers, wording is, in general, concise and that it is necessary to read every word carefully.

Q22
The frequent choice of distractor A illustrates a common misconception. Coherence occurs with constant phase difference, not just when the sources are in phase.

Q33
When plotting the variation with nucleon number of the binding energy per nucleon, textbooks do differ. Some show the line in the 1st quadrant, and others in the 2nd . Students should be familiar with both approaches.
The statistics indicate that students were not affected by this specific choice of quadrant.

Paper 2

Component grade boundaries

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 -4	5-9	10-14	15-20	21-25	26-31	32-50

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-20	21-31	32-41	42-52	53-62	63-95

General comments

The number of G2 forms returned by teachers was disappointing. Consequently, opinions expressed may not be general. Both Papers were thought to be somewhat more difficult than those for May 2004. A` significant

number thought that syllabus coverage was poor. From comments received, it may be that question A1 was included as part of Topic 12. However, question A1 is a data-based question. Knowledge of Topic 12 was not necessary. It should be remembered that the data is usually placed in some context but it is the data that is being analysed, and assessment of the subject content is not included.
The wording and presentation of the papers were thought to be either satisfactory or good by most teachers.
There were some comments related to the need to define quantities and to recall. It should be remembered` that questions in Section B should be balanced. Thus, factual recall in one question should have approximately the same weighting in others. Frequently, a definition or other factual recall is used as a means of providing a lead-in to a particular problem. Reference to the Objectives and the Action Verbs in the Subject Guide would show that recall is justified and is, in the opinion of the examiners, desirable, especially for weaker candidates.

The areas of the programme that proved difficult for the candidates

In the HL Paper and the SL Paper, question B2 was the least popular and the average mark for this question was, in general, lower than for other questions. This was largely due to very poor answers to sections (a) and (b).
There is a general problem that is not specific to a particular question or subject area. Candidates lose far too many marks through poor wording of definitions and factual recall. Definitions frequently lack precision and are expressed in non-scientific language. A thorough knowledge of definitions is important. Without this knowledge, when candidates attempt questions involving application or discussion, answers are often formulated in generalizations involving loose terminology.

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

There were no areas of the examination where it could be said that all candidates appeared to be well-prepared. The more-able candidates frequently showed some weaknesses. Less-able candidates often scored the majority of their marks in a small number of isolated areas. Candidates did, in general, attempt most sections of each question. However, such attempts frequently demonstrated a lack of knowledge and understanding of basic concepts.

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

Section A

A1 (HL and SL)

(a) With some exceptions, candidates gave the correct answer. Very few were unable to calculate the answer and the most common error was in rounding i.e. 0.429 rather than 0.430.

(b) The identification in (i) presented very few problems and, in (ii), most could plot the point to within one half of a square of the grid. However, many did not draw a reasonable best-fit line. Candidates should be encouraged to consider the scatter of points about the intended line and to arrange for the points to be distributed evenly about both sides of the line.

(c) (i) In excess of 50% of candidates gave an acceptable value for the gradient. However, candidates should be advised not to use data points unless these lie on the line of best fit or to use reference points on the best-fit line that are close together.
(ii) A common error was to assume that the line should pass through the origin. Many attempted to explain the disagreement in terms of a small difference between the value for the gradient as calculated in (i) and that calculated from the given equation.

(d) There were many correct responses here, despite inappropriate explanations in (c)(ii).

A1 (HL only)

(e) There were some good answers here, but they were in a minority. Candidates did not appear to appreciate that they needed to calculate an extreme value for $E^{-½}$, based on the value of, and uncertainty in, E. They would then be able to argue that the uncertainty in $E^{-½}$ is in the third digit.

A2 (HL only)

(a) There were very few errors in (i), (ii) and (iii). However, in (iv), it was common for the answer to be given as $27t$, rather than $27(t – 6)$.

(b) Candidates should be advised to follow the instructions given in the question. These instructions often provide advice as to how to answer a question. Some attempted the calculation without reference to their answers in (a). Those who developed an equation by equating the distance moved by the two cars were usually successful.

A2 (SL only)

(a) Most candidates did mention a centripetal force. However, the great majority of answers went on to state, or imply, that the sphere is in equilibrium, rather than explaining that the tension in the extended spring *provides* the necessary centripetal force.

(b) In most scripts, a correct expression for centripetal force was given. The most common error was in determining the tension in the spring.

A3 (HL only)

(a) Terminology was poor and consequently many lost marks. Reference was made to 'atoms' rather than 'nuclei' and 'large' rather than 'massive'. Furthermore it was not made clear what happens to a nucleus in fission when it 'splits'. Candidates should not be encouraged to paraphrase the question. 'Fusion is when nuclei fuse' does not provide any information as to the meaning of fusion.

(b) Candidates were divided into two groups. Those who completed the calculation without any apparent difficulty and those who did not know what was expected of them. A common error was to merely calculate the product of the power output and the energy released each fission.

A3 (SL only)

(a) There were some comprehensive answers but the majority lacked clarity of expression. Many merely stated that the more energetic particles would escape and so the energy of the liquid would be reduced, thus lowering the temperature. The kinetic energy is reduced, regardless as to the relative energy of the escaping molecule/atom. Candidates should be encouraged to use correct terminology and, in this case, they should refer to mean kinetic energy.

(b) Most candidates could give at least one factor. However, many did not qualify their chosen factors. The question asked for factors causing an increase in rate and thus, for example, 'increased surface area' would be correct, rather than merely 'surface area'.

(c) Candidates should be encouraged to set out and to explain their calculations. In those scripts where this was done, candidates usually scored high marks. Jumbled and incomplete equations were usually a sign of low marks.

A4 (HL only)

(a) In general, this was not answered well. Frequently, reference was made to the meaning of a photon and to photon energy, rather than giving experimental evidence.

(b) (i) Most could give the Einstein equation in symbols. The most common error was to fail to give the maximum kinetic energy in terms of V_S.

(ii) Some candidates found difficulty with the algebra when re-arranging terms to make V_S the subject of the equation. It was pleasing to note that candidates did make reference to the equation $y = mx + c$, and did compare terms with the re-arranged Einstein equation. Explanation was essential here, but weaker candidates failed to support their comments.
(iii) Candidates could use either the intercept on the graph or a point on the line. There were many correct answers but a number of candidates were unclear as to what is involved.

Section B

B1 (HL and SL)

(a) (i) In general, momentum was defined correctly. However, it was quite common to find impulse defined as rate of change of momentum.
(ii) Candidates should not paraphrase the question. Reference to momentum being conserved does not indicate any understanding of the law. The fact that there must be no external force acting on the system was omitted by many candidates.
(iii) Some candidates did not really understand how to approach the problem. Others realised that there can be no resultant force but could make no further progress. There were, however, some very good deductions.
(b) (i) Nearly all answers were correct.
(ii) For those candidates who understood the meaning of the term eV, then the calculation presented very few problems. Clearly, a minority had no real concept of the situation.
(iii) Some candidates made life difficult for themselves by calculating the mass of two protons and two neutrons to four or five significant digits. They should realise that, where the answer is given to three significant digits, such precision is quite unnecessary.
(c) (i) Frequently, the arrow drawn was so short that it could not be ascertained whether it was intended that the nucleus and the α-particle would be moving in opposite directions.
(ii) The momentum calculation was frequently completed with little or no explanation. Candidates often failed to realise that only the ratio of the masses is required and consequently, they made great efforts to calculate, in kg, the masses of the nucleus and the α-particle.
(iii) Candidates were asked to consider the effect on the paths. Instead, many concentrated on the magnitude of the velocity and completely ignored direction.

(d) **(HL only)**

(i) Candidates could consider, for example, the number of neutrons, the diameter of the nuclei or their stability. Candidates should not repeat themselves. For example, stating that the number of neutrons and the number of nucleons are different does not constitute two separate differences.
(ii) As is usual, most answers did not make it clear as to what is halving. It is necessary that the quantity being halved is stated unambiguously and that any daughter products could not possibly be included.
(iii) Generally well done with adequate explanation. The most common error was for a negative sign to appear, or disappear, mysteriously.
(iv) Many candidates did not realise that they had to use the equation $A = \lambda N$. Consequently, answers were frequently restricted to a calculation of λ.

(d) **(SL only)**

(i) Frequently, candidates mis-read the question and went on to discuss why the activity of a source does not have a life time. It was expected that reference would be made to constant probability of decay per unit time of a nucleus.

(ii) As is usual, most answers did not make it clear as to what is halving. It is necessary that the quantity being halved is stated unambiguously and that any daughter products could not possibly be included.
(iii) Axes had been labelled and quantities marked on the graph-grid. It was expected that candidates would sketch a curve passing through relevant points. However, many curves were drawn with total disregard for activity halving during each time interval equal to the half-life.
(iv) Candidates frequently handicapped themselves with poor graphs when finding the activity after 120 s. Some more-able candidates did use an equation involving exponentials in order top calculate the activity at 330 s. This was unnecessary. A 'halving' exercise was quite adequate but, despite this, many answers were incorrect.

(e) **(HL only)**

Quite intentionally, there is no simple unique answer here. Candidates could argue for either option. What was expected was some sound reasoning based on either total dose or dose-rate.

B2 (HL and SL)

(a) (i) Answers were, for the most part, poor. Most were unable to describe a travelling wave in terms of energy transfer and very few even attempted to describe the meaning of *continuous*.
(ii) It was expected that reference would be made to the speed of transfer of energy. Many referred to 'the speed at which the wave moves'.

(b) **(HL only)**

(i) Candidates frequently scored no marks. Definitions were given as generalisations that had little or no meaning. It was common to find frequency defined as the number of vibrations in a second. This gives no indication that a ratio is involved and the definition should not be given in terms of units. It would be appropriate to refer to 'per unit time' rather than 'in a second'.
(ii) Very few answers made a clear reference to *neighbouring* crests when defining wavelength.

(b) **(SL only)**

(i) Candidates frequently scored no marks. Definitions were given as generalisations that had little or no meaning. It was common to find frequency defined as the number of vibrations in a second. This gives no indication that a ratio is involved and the definition should not be given in terms of units. It would be appropriate to refer to 'per unit time' rather than 'in a second'.
(ii) Derivations were frequently confined to *speed* = *distance/time* = *wavelength/period* = *wavelength* × *frequency*, without any explanation as to the connections between the various quantities. Derivations, by their very nature, include explanation and are not merely a string of equations.

(c) **(HL and SL)**

(i) Diagrams were, in general, not relevant to the situation. Many drew a representation of a standing wave that could not possibly exist in a closed pipe. Some candidates did state that the wave would be reflected at the surface of the water. However, very few went on to explain that the standing wave is produced as a result of interference between the incident and reflected waves.
(ii) Explanations were very muddled and, frequently, did not include resonance. It was expected that candidates would describe resonance in terms of the impressed and the

natural frequencies and that the natural frequency depends on the length of the tube. Hence, changing the length would mean that resonance would no longer occur.
(iii) Nearly all answers used the equation $v = f\lambda$. However, only a small minority could give the correct value for the wavelength.

(d) **(HL and SL)**

Surprisingly, it was common to find that the correct value for the force was divided by displacement in order to calculate the pressure. Conversion of mm^2 to m^2 presented many with a difficulty.

(e) **(HL and SL)**
(i) Despite the graph being given, most answers involved *Fd*, rather than ½*Fd*, where *F* is the final force.
(ii) Any attempt to deduce the time was a very rare occurrence. However, most were able to use this given time to determine the mean power.

(iii) Candidates should realise that, at this level of examination, an answer such as 'heat' is insufficient and inappropriate. The form of the energy, and its location, should be made clear.

(f) **(HL only)**

(i) Most candidates realised that they had to use the equation $v = f\lambda$. However, the majority were unable to determine the wavelength from the path difference.
(ii) In general, statements were correct. However, only the more able candidates could give adequate explanations in terms of summing individual displacements. Explanations such as 'not complete destructive interference' were not accepted as giving sufficient detail.

B3 (HL and SL)

Part 1
(a) The *I-V* characteristics are required and thus, there must be some means of varying either *I* or *V*. Very few circuits included a variable component. It was surprising to note the large number of circuits that were totally impractical.
(b) Both parts of the section were usually completed successfully. It was pleasing to note that there were very few attempts to use a gradient to determine *R*.
(c) (i) Most did draw a straight line in quadrants 1 and 3. Generally, the gradient was correct.
(ii) Correct answers were in a minority. The vast majority of answers assumed constant resistance for X, giving a total resistance of 3.5 Ω for the circuit. Candidates were expected to read off from the graph the values of potential difference for a current of 3.0 A.

(d) **(SL only)**

Many candidates did not appear to have studied this topic and, consequently, answers were guesswork.
(i) Constant resistance was a common answer. Of those candidates who did have some understanding of the topic, a frequent, but incorrect, response was linear change of resistance with temperature.
(ii) Very few answers included any attempt to measure resistance at two known temperatures (fixed points). Consequently, a scale could not be constructed.

(HL and SL)

Part 2

(a) Candidates should be advised that the pattern of a force field includes the relative separation of the field lines. This aspect was lacking in many scripts, often as a result of very poor quality sketches.

(b) (i) Most explanations did include a reference to the magnetic field of one loop in the region of the current in the second loop. However, only rarely was it explained why there are forces on both loops (e.g. reference to Newton's third law).

(ii) Many candidates were able to give a correct expression for the force per unit length on parallel straight wires. However, there were many errors made in the substitution of the relevant distances.

(HL only)

Part 3

(a) (i) Faraday's law should be defined in terms of induced e.m.f., not induced current, and *proportionality* to rate of change of flux should be included.

(ii) There were many acceptable answers here. It should be remembered that it is necessary in such questions to state the location of the change of flux.

(b) (i) With few exceptions, the flux and the current were shown to be in phase.

(ii) Most candidates realised that the frequency of the induced e.m.f. would be unchanged but few were able to give the correct phase.

(iii) Most answers included a statement that the e.m.f. would be reduced, but the explanation was frequently either lacking or inadequate.

(c) There were some good suggestions including, as advantages, not having to interrupt the current or to approach the cable too closely. Disadvantages included the problem of judging distance from the cable and the fact that other current-carrying cables would interfere with the reading.

B4 (HL only)

Part 1

(a) (i) Despite being told to consider kinetic theory, some gave the explanation in terms of the ideal gas equation. There were some very full descriptions, spilling out beyond the suggested answer lines. Candidates should always pay attention to the mark allocation and the number of answer lines, as well as the Action Verb, when deciding how much detail to give in an answer.

(ii) Most answers did make reference to 'no potential energy'. The reason for this was not always apparent. Frequently, the link between internal energy, potential energy and random kinetic energy of molecules was not given.

(b) (i) As usual, a large number of candidates used deg. C rather than kelvin. What was surprising was that many calculated the final volume and did not determine the volume change.

(ii) The most common problem in this simple calculation was the conversion of cm^3 to m^3.

(c) (i) Candidates should be encouraged not to give a definition in terms of units. It is not the unit of specific heat capacity that is being defined.

(ii) With few exceptions, reference was made to increased speed or increased kinetic energy. However, the crucial point that it is the average, or mean, that increases was omitted by many.

(iii) Most candidates were able to state that external work is done when heating at constant pressure but not when heating at constant volume. Unfortunately, many did not draw the necessary conclusion from these statements.

Part 2
(a) Very rarely was any explanation given. Instead, equations were quoted, together with the subsequent algebra. Candidates should be encouraged to explain their working.
(b) (i) With few exceptions, the correct equations were quoted.
(ii) This part was completed correctly by most candidates.
(c) (i) Practically all candidates gave the obvious, and correct, answer.
(ii) Candidates were expected to *deduce* the result. Many made a statement, without justification.
(iii) Explanation was not required here. Regardless of the answer in (ii), many realised that the speed would increase.
(iv) Answers were disappointing with many candidates not addressing the question of increasing frictional forces. More able candidates stated that the frictional forces would increase as the height decreases but then failed to discuss how increasing drag would affect the rate of decrease of height.

Recommendations and guidance that teachers should provide for future candidates

- 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. It is not a matter of 'learning for the sake of learning'. Without this thorough knowledge, understanding may be handicapped to such an extent that 'application' and 'extension' of the subject material are highly restricted. Furthermore, the use of common language rather than scientific terminology leads to incorrect statements. A classic example of such common laguage is the use of the word 'powerful'. Candidates use this term when they mean 'greater force' or 'more energy' or, correctly 'greater rate of working'.

- Where diagrams and graphs are drawn, these should show the relevant important features. When drawing a graph, many candidates attempt to draw freehand any line using a pen. The result is that any error cannot be corrected and the line is inappropriate. Although the graph may be a sketch, candidates should ensure that the line passes through obvious important points.

- 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', 'deduce' or 'suggest', then a mere statement of the conclusion or a fallacious argument leads to no award for the conclusion.

- 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).

Paper 3

Component grade boundaries

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-9	10-14	15-17	18-21	22-24	25-40

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-14	15-20	21-26	27-31	32-37	38-60

General comments

Whilst there were some challenging questions this year, many candidates seemed to find the paper accessible. Although there were some very weak scripts there were also some of a very high standard with these candidates exhibiting an excellent understanding of the two options that they had studied.
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 sometimes gave needlessly lengthy answers to questions that were worth one mark and very brief answers to questions worth four marks. Many candidates appeared not to know that their answers should be given in the spaces provided in the examination paper and, instead, used continuation sheets unnecessarily. A few candidates answered more than two Options and it was clear that some candidates answered Options for which they had not been prepared.

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

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

Standard Level

- about 70% found the paper to be of a similar standard to last year and 30% a little more difficult. However, overall, 95% found the paper to be of an appropriate standard and 5% thought it too difficult
- about 40% found the syllabus coverage satisfactory and 60% good
- about 30% found the clarity of wording satisfactory and 70% found it good
- about 20% found the presentation satisfactory and 80% found it good.
- As in previous years, the most popular options were A (Mechanics) and H (Optics).

Higher Level

- about 70% found the paper to be of a similar standard to last year, 10% a little easier and 20% a little more difficult. However, overall, 92% found the paper to be of an appropriate standard, 3% thought it too difficult and 5% found it too easy
- about 40% found the syllabus coverage satisfactory and 60% good
- about 40% found the clarity of wording satisfactory and 60% found it good
- about 30% found the presentation satisfactory and 70% found it good.
- As in previous years, the most popular options were H (Optics), G (Relativity) and F (Astrophysics).

The areas of the programme that proved difficult for the candidates

As in past examinations candidates displayed weakness in the use of the lens equation and in the construction of ray diagrams. The use of moments in option A at Standard Level was frequently incorrect. Definitions were often incomplete and lacking in precision, as were extended responses. In the latter, many answers relied on anecdote rather than principles of physics.
Areas that caused problems included:

- projectile motion
- gravitational field strength
- extended objects in equilibrium
- concepts of particle and antiparticle production and conservation laws
- thermodynamic processes
- attenuation coefficients and half-value thickness
- sound intensity and sound intensity levels
- Chadwick's discovery of the neutron
- concept of apparent brightness
- Olber's paradox
- Michelson –Morley experiment
- relativistic dynamics
- principle of equivalence
- critical angle
- construction of ray diagrams
- resolution

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

- There was general success with using equations and substitution of numerical values into formulae.

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

SL only
A and H would appear to have been the most popular two Options.

Option A – Mechanics

Question 1 Projectile motion

A significantly large number of candidates drew a vertical distance against horizontal distance graph.
Explanations in terms of conservation of energy were often incomplete in the respect that conservation of energy was not mentioned.

Question 2 Gravitational fields

This question was not done well. Definitions of field strength quite often were just not definitions –" the force that planets feel". Reference to a small or point mass was rarely made.
Those candidates who managed to get (b)(i) correct, often went on to estimate a correct value for the mass of Jupiter.

Question 3 A weighing device

The condition for rotational equilibrium was often missing.
Several candidates gave a correct answer to part (c) based on a clearly expressed symmetry argument and were awarded full credit.
The question overall demonstrated that many candidates find working with algebraic symbols difficult.

Option B - Atomic and nuclear physics extension
This was not a popular Option

Question 1 The photoelectric effect

There were few good accounts as to how the Einstein theory accounts for the existence of a threshold frequency. Many lacked clarity and rarely was any mention made of the fact electrons require energy to be ejected from a metal surface.
Many candidates were able to correctly find a value of the threshold frequency but few were able to find a correct value for the work function.

Question 2 Radioactive decay

The decay equation was often completed correctly but the problem defeated many candidates with many not knowing how to begin.

Question 3 Particles and their conservation laws

Part (a) was often answered well but very few candidates recognized that conservation of lepton number would be violated in the second quoted reaction.

Option C - Energy extension
This was not a popular option.

Question 1 Heat pump

Annotated diagrams were often done well but the calculation was not.

Likewise, although the two processes were often explained correctly, it was rarely that a good explanation was provided as to during which process energy was absorbed from the outside of the house.

Question 2 Wind energy

Arithmetic manipulation was the downfall of many candidates in this question.
Many candidates correctly identified and explained a disadvantage of wind power generation.

SL and HL combined

Option D - Biomedical physics

Question 1 Scaling

A small minority of students had clearly practiced scaling questions and did well. The rest of the students who attempted this question did not understand what was involved. As in previous years, the mark distribution was either all or nearly nothing.

Question 2 Hearing loss

This would seem to be an area with which candidates are confident. Apart from some very weak scripts, this was answered quite well.

Question 3 X-rays

X-ray quality was not generally understood but half-value thickness was.

AHL

Question 4 Body temperature

Although there were some good answers to this question, lack of knowledge and an inability to apply calorimetry to a real situation, produced a lot of weak responses.

Question 5 Dosimetry

The term relative biological effectiveness was not known by many candidates and the problem also defeated many. This would seem to be an area of the option that is generally not known well.

Option E – The history and development of physics

Question 1 Models of the universe

There were few references to “spheres” in the descriptions of the Ptolemaic model.

Question 2 Motion and force

Apart from describing how Galileo’s theory explained the motion of the block, this question was generally quite well answered.

Question 3 The atom and the nucleus

This question was not generally answered well. Most candidates could distinguish between the Thompson and Rutherford model of the atom but Chadwick’s work on the nucleus was not well known.

AHL

Question 4 The hydrogen atom

Apart from knowing the other Bohr postulate, this question was very poorly answered. The algebraic manipulation defeated many candidates and few could convincingly outline how the Schrodinger model accounts for the existence of energy levels.

Option F – Astrophysics

A popular Option particularly at Higher Level.

Question 1 Stellar radiation and Betelgeuse

The first part on black-body radiation was generally done well but a disappointingly large number of candidates could not give precise definitions to luminosity and apparent brightness. Apparent brightness was often confused with apparent magnitude. The calculation defeated many candidates; as in previous years, candidates found difficulty in handling ratios.

Question 2 Olber's paradox

For one of Newton's other assumptions about the universe, many candidates stated "the universe is uniform" rather than stating that the distribution of the stars is uniform. This is yet another example of where candidates' answers often lack precision.

Good quantitative answers to describing Olber's paradox were rare; the argument that every line of sight ends on a star was that most commonly evoked. However, red-shift was known well.

AHL

Question 3 Stellar evolution

The majority of candidates had some idea about the evolution of the Sun, but few candidates placed red giants and white dwarves in the appropriate region of the HR diagram. Some placed black holes and neutron stars on the grid.

Few candidates appreciated that high mass stars can lose 80-90% of their mass during the planetary nebula phase and thereby reduce their mass below that of the Chandrasekhar limit.

Option G - Special and general relativity

This was a popular Option at Higher Level

Question 1 Reference frames

Descriptions of a frame of reference were often poor with many candidates thinking a reference frame only applies to Special Relativity.

Most candidates realised that a Galilean transformation leads to differing values for the speed of light but not many could use the velocity transformation equations to show the constancy of the speed of light.

As in previous years, the concept of proper time is not well understood. There is a feeling amongst some candidates that, despite what Special Relativity teaches, there is an absolute reference frame in which the value of time is the "true" value. Despite this, the problem was often done well.

Question 2 The Michelson-Morley experiment

Many candidates knew the purpose and the outcome of this experiment but were hazy concerning the experimental details.

AHL

Question 3 Relativistic dynamics

The better candidates did well on this question, particularly those who were confident in using $MeVc^{-2}$ and MeV units.

Question 4 Gravitational red-shift

This was invariably poorly answered. Candidates could recall some facts about the situations but could not use them in a structured way to form a coherent argument.

Option H – Optics

This was a popular Option both at SL and HL, but as in previous years, was not often answered with confidence.

Question 1 Critical angle

Ray diagrams were often poor. The impression was that they were half-remembered rather than constructed. The critical angle was often incorrectly identified.
Quite a few candidates could get as far as calculating the critical angle but were then defeated by the geometry.

Question 2 The astronomical telescope

The first part of this question is essentially recall of standard bookwork and as such should generally be expected to attract good marks. However, the definition of focal length was often incorrect or incomplete and, as in previous years, ray diagrams were often very poor.
It is accepted by the Examining Team the eye ring is not in the syllabus but it should be noted that knowledge of this is not actually required to solve the problem. The question is essentially setting up a situation in which the candidates have to locate the position of the image of the objective lens formed by the eyepiece. With hindsight, it might have been preferable to have omitted the last two sentences in the stem thereby reducing the amount of words.

AHL

Question 3 Optical resolution

The diagrams were often done well (but too many of them did not have intensity distributions that touched the x-axis) but, as in previous years, the problem was not well done. The use of the small angle approximation would seem to confuse many candidates.

Question 4 Multi-slit diffraction

Diagrams were often weak but the problem was often solved correctly.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team included the following ideas:

- It is important that Options are not left until the end of the course. This can lead to their study being rushed or incomplete. The time available for the study of the Options should be allowed for and carefully integrated into the programme as a whole. Candidates should not attempt to answer an Option that they have not studied.
- If candidates study an Option on their own, then teachers should ensure that their progress is carefully monitored and that adequate support is given. Candidates from the same school who answered questions in the same two options generally performed better than candidates from the same school who answered questions from several different options.
- Candidates should read each question carefully before answering.
- Answers must be focused – there is no need to write unnecessarily long sentences.
- Candidates must ensure that they are familiar with the definitions of physical quantities. The definitions must be precise, accurate and detailed.
- Candidates should use the number of marks allotted a given part of a question as a rough guide to the amount of detail required in their answers.
- Candidates should be encouraged to produce clear and labelled diagrams.
- Candidates should check their answers and see if they make sense e.g. the distance to a star cannot be 2×10^{-18} m.
- Candidates should be familiar with the contents of the Data Booklet.
- Answers must be written in the appropriate space on the examination paper itself and additional sheets used only if required.
- Candidates should not answer in pencil as this is often difficult to decipher.
- More practice is needed with the interpretation of data – particularly when the data is presented in graphical form.
- Candidates should practice with the manipulation of ratios both in numeric and in symbolic form.

