Physics

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-28	29-40	41-51	52-60	61-71	72-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-27	28-37	38-48	49-58	59-69	70-100

Standard level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-13	14-15	16-18	19-20	21-29

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-15	16-20	21-23	24-26	27-29	30-39

IB multiple choice physics papers are designed to have, in the main, questions testing conceptual ideas rather than the ability to carry out calculations. Calculations can be assessed more appropriately in questions on Papers 2 and 3. Calculators are thus neither needed nor allowed for Paper 1. A proportion of questions are common to the SL and HL papers, and the additional questions in HL provide further syllabus coverage.

The May 2003 papers were generally well received. Approximately 90% (at SL) and 88% (at HL) of the teachers who commented on the Papers felt that they contained questions of an appropriate level. A small number thought that both Papers were a little more difficult. With few exceptions, teachers thought that the Paper gave satisfactory or good coverage of the syllabus (96% at SL and 97% at HL). However, coverage should be judged in conjunction with Papers 2 and 3. All teachers also felt that the presentation of the Papers was either satisfactory or good. However, it was pointed out that a small number of questions were ambiguous or contained errors. Further comment will be made on these questions later in this Report.

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	171	2575*	313	1930	3	51.57	.48
2	407	668	3534*	364	20	70.77	.49
3	3090*	838	529	524	12	61.88	.40
4	2473*	378	2038	89	15	49.52	.56
5	824	847	290	3019*	13	60.46	.46
6	629	2083*	1777	485	19	41.71	.41
7	32	3725*	614	617	5	74.60	.32
8	1422*	2323	381	846	21	28.47	.34
9	2783*	837	257	1103	13	55.73	.44
10	2344*	1303	1003	331	12	46.94	.21
11	978	1237	1183	1570*	25	31.44	.49
12	1306	112	2949*	596	30	59.06	.41
13	2937*		892	1152	11	58.82	.29
14	525	3278*	229	951	10	65.65	.39
15	744*	175	764	3300	10	14.90	.24
16	658	992*	1134	2170	39	19.86	.04
17	400	331	105	4150*	7	83.11	.32
18	67	3126*	1000	792	8	62.60	.41
19	141	922	2787*	1132	11	55.81	.35
20	1036*	1583	1792	531	51	20.74	.15
21	476	3981*	182	336	18	79.73	.33
22	213	622	4076*	73	9	81.63	.18
23	3441*	960	149	433	10	68.91	.39
24	592	3395*	548	371	87	67.99	.32
25	3075	746*	486	640	46	14.94	.03
26	534	221	384	3838*	16	76.86	.42
27	2014*	1087	948	880	64	40.33	.35
28	406	513	2667*	1377	30	53.41	.43
29	1007	1015	1645	1240	86		
30	1290	2206*	435	982	80	44.18	.57

In Q13 above A and B were both marked correct. Q29 was removed from the paper.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	472	2151*	782	51	9	62.07	.55
2	2487*	425	350	199	4	71.77	.38
3	1804*	950	541	158	12	52.06	.36
4	2625*	331	105	99	5	75.75	.40
5	809	516	532	1602*	6	46.23	.43
6	272	1784*	224	1182	3	51.48	.07
7	357	320	2773*		15	80.02	.27
8	2094*	529	572	263	7	60.43	.32
9	2498*	479	316	168	4	72.09	.18
10	390	481	2068*	526		59.68	.40
11	147	2616*	116	582	4	75.49	.29
12	697*	73	333	258	4	20.11	.31
13	2163*	909	282	103	8	62.42	.48
14	309	1673*	333	1146	4	48.28	.32
15	94	644	2370*	355	2	68.39	.24
16	406	649*	633	1752	25	18.73	.02
17	131	100	37	3197*		92.26	.15
18	857	401	1000	1192*	15	34.40	.36
19	35	2577*	489	357	7	74.37	.39
20	988*	1812	583	81	1	28.51	.31
21	270	44	3093*	5	5	89.26	.20
22	584	218	2616*	45	2	75.49	.37
23	373	2004*	585	490	13	57.83	.50
24	2551	815*	82	14	3	23.52	.06
25	2651*	562	59	193		76.50	.28
26	324	2557*	321	208	55	73.79	.34
27	196	491	1980*	788	10	57.14	.36
28	808	468	980	1180*	29	34.05	.26
29	55	1032*	2284	88	6	29.78	.16
30	2186*	818	234	215	12	63.08	.36
31	357	899	2055*	137	17	59.30	.33
32	469	685	987	1300*	24	37.51	.16
33	118	2240*	347	744	16	64.64	.48
34	1607	596	329	918*	15	26.49	.31
35	2063*	459	442	485	16	59.53	.45
36	2220*	293	715	222	15	64.06	.44
37	365	2425*		663	12	69.98	.25
38	72	156	495	2722*	20	78.55	.27
39	562	674	1251	948	30		
40	1103	1188*	677	462	35	34.28	.33

In Q7 above C and D were both marked correct and in Q37 both B and C were marked correct. Q 39 was removed from the paper.

Comments on the analysis

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

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

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

Comments on selected questions

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

SL paper 1 comments on selected questions

Question 3

Candidates should be familiar with changing slopes (gradients) of graphs. In this case, a negative slope indicates a negative acceleration and a positive slope a positive acceleration. A zero slope indicates zero acceleration.

Question 8

The question does define K as kinetic energy even though the data booklet uses $E_K = \frac{p^2}{2m}$.

Writing $\frac{E_{K_1}}{E_{K_2}}$ was considered to be too clumsy.

Question 9

The definition of the eV is on the syllabus.

Question 11

A satellite orbiting at a distance of $2r$ from the Earth's centre would have a speed of $\frac{v}{\sqrt{2}}$, and not $\frac{v}{2}$, where v is the speed of a satellite orbiting at a distance of r. This was an unfortunate mistake. The question asked for the *centripetal force*, which should have led candidates to the formula $\frac{mv^2}{r}$. In that case the ratio of forces (S_1 to S_2) is $\frac{\frac{mv^2}{r}}{\frac{m(v/2)^2}{2r}} = 8$. It would have been potentially confusing for those candidates with knowledge of gravitation (not on the core syllabus) who might use centripetal force = gravitational force (weight) = $\frac{GMm}{r^2}$ and so deduce that the ratio of forces (S_1 to S_2) is $\frac{\frac{GMm}{r^2}}{\frac{GMm}{4r^2}} = 4$. The statistics of this question showed that most answered this by just guessing but at the same time it showed good discrimination between the strong and weak candidates.

Question 13

This question did not specify the direction of thermal energy transfer. On a hot sunny day a room with large glass windows would mainly be heated by radiation but at night it would be losing heat mainly by conduction. Therefore both A and B were marked as correct answers to this question.

Question 14

The word "centigrade" is not an SI unit for temperature but this did not disadvantage the candidates as it appeared in just option A, a distractor.

Question 15

In this question the word "rate" is to be understood as synonymous to the word "frequency". This did not cause any problems for the candidates.

Question 16

The phrase "perpendicular to the direction of travel of the waves" was confusing. This question had a very low discrimination index indicating that the good candidates did not get this question right and that those who did probably did so by guesswork.

Question 23

The definition of resistance is $R = \frac{V}{I}$ where the values of voltage and current are taken at the point of interest. The resistance is not the gradient of the V-I curve.

Question 25

This question was meant to test understanding of the fact that it is the component of the magnetic field normal to the current that is responsible for the magnetic force.

Question 29

This question was removed from the Paper. The syllabus guide refers to a graph of average binding energy per nucleon plotted against atomic number but all textbooks show graphs with mass number on the horizontal axis. Teachers are encouraged to teach the standard version of this graph, namely binding energy per nucleon as a function of mass number.

HL paper 1 comments on selected questions

Question 5

A satellite orbiting at a distance of 2*r* from the Earth's centre would have a speed of $\frac{v}{\sqrt{2}}$, and not $\frac{v}{2}$, where *v* is the speed of a satellite orbiting at a distance of *r*. This was an unfortunate mistake. The question asked for the *centripetal force*, which should have led candidates to the formula $\frac{mv^2}{r}$. In that case the ratio of forces (S_1 to S_2) is $\frac{\frac{mv^2}{r}}{\frac{m(v/2)^2}{2r}} = 8$. It must have been confusing, however, for Higher Level candidates with knowledge of gravitation who might use centripetal force = gravitational force (weight) = $\frac{GMm}{r^2}$ and so deduce that the ratio of forces (S_1 to S_2) is $\frac{\frac{GMm}{r^2}}{\frac{GMm}{4r^2}} = 4$.

Question 7

Answers C and D were both accepted as correct for this question. The obvious answer is C since the force on the spacecraft is not constant, resulting in a velocity that does not vary uniformly with time. However, it could be argued that if point P is very close to the spacecraft when the engines are turned off, the variation of g with distance would be negligible resulting in a constant force on the spacecraft, hence answer D.

Question 9

This question is based on material in the syllabus. Refer to 2.1.9 in the Syllabus Guide.

Question 10

The comment here is for French candidates only. The phrase "as seen by Lucie" was missing in the French paper. Candidates were not disadvantaged by this omission as both C and D were marked correct.

Question 12

In this question the word "rate" is to be understood as synonymous to the word "frequency". This did not cause any problems for the candidates.

Question 14

The labels Q_c and Q_h were interchanged in option B (English version only.) This did not disadvantage the candidates as seen by the statistics of this question.

Question 16

The phrase "perpendicular to the direction of travel of the waves" was confusing. This question had a very low discrimination index indicating that the good candidates did not get this question right and that those who did probably did so by a lucky guess.

Question 20

The symbol c is generally used to denote wave speed and need not always stand for the speed of light.

Question 24

This was a difficult question with the majority of candidates answering, incorrectly, option A. The two forces on the sphere as it falls are both constant and application of vector addition gives a *constant* force (in magnitude and direction) at an angle to the vertical.

Question 25

The definition of resistance is $R = \frac{V}{I}$ where the values of voltage and current are taken at the point of interest. The resistance is not the gradient of the V-I curve.

Question 28

This was a difficult and challenging question but one that discriminated quite well. Candidates should be able to deduce that in Y the electron has a smaller radius and thus a smaller speed indicating energy loss in the foil.

Question 29

The angle shown in the diagram is not the angle in the definition. Candidates had to think about the definition of magnetic flux and apply the definition accordingly.

Question 30

This question is based on material on the syllabus and does not require knowledge of simple harmonic motion. Since the frequency halves, the period will double and so the rate at which flux is being cut also halves. Hence the answer is A. This was a good question with a high discrimination index.

Question 33

The labeling on the vertical axis was unfortunate but it did not confuse anybody. (It should have been $E_{\max}$).

Question 37

The question did not specify that the ions all had the same charge and so answers B and C were both accepted as correct.

Question 39

This question was removed from the Paper. The syllabus guide refers to a graph of average binding energy per nucleon plotted against atomic number but all textbooks show graphs with mass number on the horizontal axis. Teachers are encouraged to teach the standard version of this graph, namely binding energy per nucleon as a function of mass number.

Question 40

Conservation laws, such as baryon and lepton number, are part of the syllabus.

Examiner comment

In general, conceptual questions of the type used in these multiple choice papers demand good understanding of basic concepts and principles, often more so than quantitative formula-based problems. They require insight into situations and the ability to apply qualitative reasoning to understand how various factors affect a system. These skills, an important component of 'thinking like a scientist', sometimes tend to be neglected in teaching and in textbooks. Thus it is not surprising that some candidates struggled with the conceptual nature of the questions. Nevertheless, it is encouraging that many candidates scored high marks and demonstrated good preparation for the examination.

Standard level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-11	12-16	17-21	22-27	28-32	33-50

General comments

Judging from the very few critical comments on the teacher feedback forms, the examination would seem to have been well received by schools. It should be noted that fewer than 50% of schools completed these forms.

Feedback from schools can be summarized as follows:

- about 67% found the paper to be of a similar standard to last year, 5% a little easier, 23% a little more difficult and 5% much more difficult
- about 85% found the level of difficulty appropriate and about 15% too difficult
- about 56% found the syllabus coverage satisfactory 32% good and 12% poor
- about 60% found the clarity of wording satisfactory, 35% found it good and 5% poor
- about 50% found the presentation satisfactory and 50% found it good.

The examination would seem to have offered suitable challenges to strong candidates and also appropriate accessibility to weaker candidates.
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 heed to the space available for answering a particular sub-question or to the marks available and hence gave needlessly lengthy answers. Furthermore, many wasted time and space by paraphrasing the question, rather than answering it.

The general impression was that fewer candidates made significant digit errors and/or unit errors for which marks were deducted.

The majority of candidates showed the steps in calculations and so were able to take advantage of "error carried forward" marks. However, some candidates still continue not to show their working and so lose partial marks when the answer that they write down is incorrect. This is a serious problem for a minority of candidates.

In Section B, question B1 was by far the most popular choice. However, this does not mean that the marks scored by candidates were, on average, higher. Popularity cannot be equated with high overall marks.

The areas of the programme that proved difficult for the candidates

Often, the impression gained from scripts is that candidates are using the equations given in the Data Booklet without thought.
The interpretation of graphical data and explanations of physical phenomena are beyond some candidates.

In this examination, the following topics proved difficult for many candidates:

- the interpretation of experimental data
- work done and centripetal force
- interpretation of wave diagrams and v-t graphs
- the paths of charged particles in force-fields
- momentum conservation associated with nuclear decay

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

In general, many candidates seemed to be well prepared in respect of the following topics:

- graph plotting
- ideal gas calculations
- basic wave properties
- nuclear equations

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

Section A

Question 1 Data analysis

It was common to find that candidates thought that the balance reading would be constant when the water is boiling steadily. However, many did refer to either constant temperature or a steady rate of production of bubbles. Very few candidates appreciated the reason for taking two intervals instead of one. Many referred vaguely to it being "more accurate" without saying why. It was pleasing to note that, when determining the gradient, very few used two points on the line that were close together.Very few candidates were able to determine the specific latent heat. Most answers did not include any factor to allow for the time of collection of the water.
There were some good responses but many referred to 'errors in the meters' or 'energy losses in the variable resistor'.

Question 2 Satellite motion

Many drew correct arrows but a surprisingly large number of weaker candidates did not score full credit.
The concept that a changing velocity implies acceleration was generally well expressed.
The wording of the question in (c) did lead to some confusion. Some candidates interpreted the word 'work' as meaning 'acts on'. Candidates should realise that, in physics, 'work' is a defined quantity.

Question 3 Ideal gases

Many gave partial answers as to what is meant by an ideal gas. It was acceptable to answer the question in terms of either macroscopic properties or microscopic properties, but not a mixture of both.
A significant number of candidates attempted the calculation using the units of atmospheres, and litres, with R = 0.082 litre atmos K^{-1}. When converting to this system of units, errors were very common. It needs to be stressed that whilst the IB cannot legislate as to what system of units a candidate uses, it is expected that candidates will be able to work in the SI system of units.

Section B

Question 1 Waves and wave properties

A large number of candidates were not able to define a wavefront, nor even explain what is meant by a ray. Perhaps this aspect is something taken for granted in the teaching of waves. With few exceptions, the wavefronts drawn were acceptable. However, explanations rarely went beyond a vague comment about bending wavefronts. Candidates were expected to consider either angles at the boundary or the separation of wavefronts when coming to a conclusion.
The work in (c) is an interpretation of a *v*-*t* graph and not, as some teachers thought, a question on simple harmonic motion.
A surprisingly large number of candidates failed to determine the frequency. The main problem was interpreting the units on the *x*- axis (milliseconds). This was also seen in answers as to the area under the graph. Furthermore, candidates should realise that the area is

greater than the area of the triangle enclosed in the loop. The physical significance of the calculated quantity (the amplitude) was appreciated by only the more able candidates.
Candidates found difficulty in clearly distinguishing between the two types of wave. The calculation in (e)(ii) presented very few problems, provided that a wavelength had been identified.

Question 2 Forces on charged particles

It is always disappointing to find candidates losing marks through careless drawing. It is expected that main features will be shown, for example, the parallel field lines equally spaced and normal to the plates. A parabolic path for the charged particle was not required but it is reasonable to expect to see a smooth curve between the plates and a straight path when outside the field.
As is usual in these calculations, there were some candidates who did not know how to begin the task. Candidates should always remember that, where they are asked to deduce a result, the marks are awarded for the working, not the result.
When drawing the magnetic field lines, diagrams were frequently too poor to be awarded credit. Field lines should not touch or cross!
There was a marked division between candidates. Some had little idea as to how to approach the calculations but it was obvious that some were well-practised in taking components and consequently performed well.
This final part of the question proved to be a good discriminator. Either a spiral or a helix (correct) was accepted by the examiners.

Question 3 Nuclear reactions

Very rarely was it appreciated that changes in temperature and pressure do not affect rate of decay.
Most candidates were able to complete the equation.
The calculation was not often correct, as few candidates calculated the mass defect first. As a result, they got into difficulties with the complexities of the equation, and an inability to use index notation.
This simple momentum problem was made complex for a significant number of candidates by putting it in the context of a nuclear decay. Candidates appear to learn their physics in ‘compartments’. Few succeeded in obtaining the ratio in (ii), and even fewer completed the deduction in part related to the kinetic energies in part (iii).
The concept of fusion was generally well understood. However, the conditions required for it to occur, in terms of overcoming proton repulsion, was not well understood.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team include the following ideas.

- More practice is needed with the interpretation of data – particularly if the data is presented in graphical form.
- More practice with algebraic manipulation. Candidates can be encouraged to first attempt the manipulation using numerical values and then see how this can be generalised.
- Intermediate stages should be shown in calculations and deductions, rather than attempting to ‘carry’ data in calculator memories.

- More emphasis should be placed on the need for answers to be precise and detailed. The number of marks awarded for a question can always be taken as a guide to the amount of detail required.

In general, candidates should

- be given precise and unambiguous definitions of physical quantities.
- always be encouraged to read carefully all the questions in Section B before making any choice.
- gain experience in answering examination questions early on in the course, when a particular topic is completed. Relevant questions (or parts of questions) from past examinations should be used to reinforce the understanding of the topic.
- use a ruler to draw straight lines in diagrams or for linear graphs.
- use pencil for diagrams and sketches.

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-21	22-32	33-42	43-52	53-62	63-95

General comments

Judging from the very few critical comments on the teacher feedback forms, the examination would seem to have been well received by most schools and colleges.
Fewer than 50% of schools returned feedback forms. The results of the available feedback can be summarised as follows:

- about 53% found the paper to be of a similar standard to last year, 6% a little easier, 35% a little more difficult and 6% much more difficult
- about 85% found the level of difficulty appropriate and about 15% too difficult
- about 47% found the syllabus coverage satisfactory, 33% good and 20% poor
- about 60% found the clarity of wording satisfactory, 35% found it good and 5% poor
- about 45% found the presentation satisfactory and 55% found it good.

The examination would seem to have offered suitable challenges to strong candidates and also appropriate accessibility to weaker candidates.
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, do not pay attention to the space available for answering a particular sub-question or to the marks available, resulting in needlessly lengthy answers. Furthermore, many wasted time and space by paraphrasing the question, rather than answering it.

The general impression was that fewer candidates made significant digit errors and/or unit errors for which marks were deducted.

The majority of candidates showed the steps in calculations and so were able to take advantage of "error carried forward" marks. However, some candidates still continue not to show their working and so lose partial marks when the answer that they write down is incorrect.

In Section B, question B1 was the most popular and question B4 was the least popular. Poluparity did not appear to correlate with higher marks.

The areas of the programme that proved difficult for the candidates

The manipulation of data (as opposed to substituting numbers into equations) caused problems for many candidates.
Often, the impression gained from scripts is that candidates are using the equations given in the Data Booklet without thought.
The interpretation of graphical data and explanations of physical phenomena is beyond some candidates.

In this examination, the following topics proved difficult for many candidates:

- the interpretation of experimental data
- electromagnetic induction
- interpretation of wave diagrams and *v*-*t* graphs
- interference of waves
- explanations based on kinetic theory
- decay constant
- deducing the direction of the resultant force in force-fields

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

In general, many candidates seemed to be well prepared in respect of the following topics:

- graph plotting
- ideal gas equations
- basic wave properties
- radioactive decay

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

Section A

Question 1 Data analysis

It was common to find that candidates thought that the balance reading would be constant when the water is boiling steadily. However, many did refer to either constant temperature or a steady rate of production of bubbles.
Very few candidates appreciated the reason for taking two intervals instead of one. Many referred vaguely to it being "more accurate" without saying why.
It was pleasing to note that, when determining the gradient, very few used two points on the

line that were close together.
Very few candidates were able to determine the specific latent heat. Most answers did not include any factor to allow for the time of collection of the water.
There were some good responses but many referred to 'errors in the meters' or 'energy losses in the variable resistor'.

Question 2 Ideal gases

Many gave partial answers as to what is meant by an ideal gas. It was acceptable to answer the question in terms of either macroscopic properties or microscopic properties, but not a mixture of both.
A significant number of candidates attempted the calculation using the units of atmospheres, and litres, with R = 0.082 litre atmos K^{-1}. When converting to this system of units, errors were very common. It needs to be stressed that whilst the IB cannot legislate as to what system of units a candidate uses, it is expected that candidates will be able to work in the SI system of units.
When finding the average volume, some simple arithmetical errors were made, leading to ridiculous answers. Candidates should be encouraged to look at their results to check to see whether the results of calculations are reasonable. A solution based on a sphere, rather than a cube, was an acceptable alternative when estimating atomic separations.

Question 3 Photons

The first part of the question could be done by most candidates. However, many lost marks because they gave insufficient explanation to show how they arrived at the given answers.
Weaker candidates were unable to determine the change in momentum. Surprisingly, a significant number of candidates did not realize that they should simply multiply together the number of photons per second and the momentum of each photon.
More able candidates realised the connection between change in momentum per second on unit area and pressure. Answers as to whether the pressure would increase were very disappointing. Very few realised that the pressure would increase and even fewer could give a valid explanation. Most thought that the pressure would be reduced because the photons would no longer be stopped by the surface.

Question 4 Electromagnetic induction

The majority of candidates correctly identified the points M and Z but with weaker candidates, M and Z were often shown with a π rad phase angle between them.
It should be noted that the polarity of the magnet is not important when explaining the alternating nature of the e.m.f. What is important is the 'direction of cutting' of the lines of flux. Some candidates dealt only with the magnitude of the induced e.m.f. and thus scored no marks. Others did not relate the 'direction of cutting' to Lenz's law.
The question proved to be a good discriminator between candidates.

Section B

Question 1 Waves and wave properties

With few exceptions, the wavefronts drawn were acceptable. However, explanations rarely went beyond a vague comment about bending wavefronts. Candidates were expected to consider either angles at the boundary or the separation of wavefronts when coming to a conclusion.
The work in (b) is an interpretation of a v-t graph and not, as some teachers thought, a question on simple harmonic motion.

A surprisingly large number of candidates failed to determine the frequency. The main problem was interpreting the units on the *x*- axis (milliseconds). This was also seen in answers as to the area under the graph. Furthermore, candidates should realise that the area is greater than the area of the triangle enclosed in the loop. The physical significance of the calculated quantity (the amplitude) was appreciated by only the more able candidates.
Statements relating to the principle of superposition were disappointing. Surprisingly few candidates realized that it is the displacements, not the amplitudes, that are summed and many did not state that the waves must meet at a point. Answers to the two-source problem were all too often little more than statements. It was expected that path differences would be considered, leading to conclusions based on whether the interference is constructive or destructive. Many did not appreciate that destructive interference does not always give rise zero amplitude.
The non-observance of fringes using monochromatic light was usually explained on the basis that the fringes would be narrow. Very rarely was coherence mentioned.
The part of the question based on the Doppler effect was either done well or done poorly. It appears as if a significant proportion of candidates had not studied the phenomenon.

Question 2 Work, energy and power

The complete definition was given by very few candidates. Many failed to make a mention of direction. Candidates should be discouraged from giving an algebraic equation without explanation when attempting a definition.
Derivations were frequently inadequate in that insufficient explanation was given. Candidates should realise that they are expected to show clearly the physics of situations, and not put all the emphasis on algebraic manipulations.
The discussion of the energy changes was poorly done by the majority of candidates as they did not read the question carefully enough. They assumed that the situation could be explained as an increase in kinetic energy at the expense of the gravitational potential energy and that air resistance played no part in the explanation.
Internal energy was explained satisfactorily in most cases. However, very few could explain the rise in temperature. A large majority thought that the reduction in volume, leading to an increased collision rate, would raise the temperature. A significant number even attributed the rise in temperature to friction when the atoms collided with the walls! Very few realised that collisions with the moving piston would give rise to an increased mean speed for the atoms.
Apart from those candidates who did not use the SI system of units, the calculations based on the indicator diagram presented very few problems. However, when attempting to find the efficiency, a significant proportion of candidates tried to use temperatures, rather than energy input and output.

Question 3 Nuclear reactions

Very rarely was it appreciated that changes in temperature and pressure do not affect rate of decay.
Approximately 50% of candidates could relate decay constant to a probability of decay.
However, many seemed to be unsure as to what would decay and in what length of time.
The calculation was usually correct, but some candidates did not calculate the mass defect first. As a result, they got into difficulties with the complexities of the equation and an inability to use index notation.
This simple momentum problem was explained satisfactorily by the more able candidates. Weaker candidates appear to learn their physics in ‘compartments’ and consequently were unable to give an explanation despite being told to consider momentum. Most succeeded in obtaining the ratio in (ii) even when their earlier explanations were unsatisfactory.

The calculations based on radioactive decay proved to be accessible to most candidates although a significant number did not understand how to determine the average activity of the sample.
The concept of fusion was generally well understood. However, the conditions required for it to occur, in terms of overcoming proton repulsion, were not well understood by weaker candidates.

Question 4 Forces on charged particles

Answers were very disappointing. The vast majority merely named the field. When candidates are asked to *deduce*, then an explanation must be given.
Only the weaker candidates had difficulty in deducing the speed of the electron.
Surprisingly, the arrow was frequently drawn at some position other than P. Most candidates completed the calculations successfully.
It was pleasing to note that many answers made reference to gravitational effects being negligible and also, in the case of more able candidates, they compared the gravitational force to either the electric force or the magnetic force.
It was evident that, for some weaker candidates, the remainder of this question was guesswork. In answers where the direction of the magnetic field was predicted correctly, candidates frequently failed to mention the rule they had used in order to find the direction.
There was a small number of good answers to the problem when speed, mass and/or charge are changed. Others failed to consider both the magnitudes and the directions of the forces on the particles.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team include the following ideas.

- More practice is needed with the interpretation of data – particularly if the data is presented in graphical form.
- More practice with algebraic manipulation. Candidates should be encouraged to first attempt the manipulation using numerical values and then see how this can be generalised.
- Intermediate stages should be shown in calculations and deductions, rather than attempting to ‘carry’ data in calculator memories.
- Where a deduction is expected, then explanation as to how the answer is obtained is necessary.
- More emphasis should be placed on the need for answers to be precise and detailed.
- The number of marks awarded for a question can always be taken as a guide to the amount of detail required.

In general, candidates should

- be given precise and unambiguous definitions of physical quantities.
- always be encouraged to read the all questions in Section B carefully before making any choice.
- gain experience in answering examination questions early on in the course. When a particular topic is completed, then relevant questions (or parts of questions) from past examinations should be used to reinforce the understanding of the topic.
- be encouraged to always show their working in the answers to numerical questions.

- use a ruler to draw straight lines on diagrams or on linear graphs
- use pencil for diagrams and sketches.

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-9	10-13	14-18	19-22	23-27	28-40

General comments

The G2 feedback forms submitted after the examination contained both praise and constructive criticism. The critical comments were taken into careful consideration during the grade award process in making judgements about the overall level of difficulty and the likely effect of particular questions on candidates. The process of setting grade boundaries is responsive to teacher feedback and teachers are urged to submit their comments (if they have any) on the form G2. The feedback can be summarized as follows:

- about 60% found the paper to be of a similar standard to last year, 20% a little easier and 20% a little more difficult. However, overall, 90% found the paper to be of an appropriate standard and 10% thought it too difficult.
- about 64% found the syllabus coverage satisfactory and 36% good
- about 56% found the clarity of wording satisfactory and 44% found it good
- about 48% found the presentation satisfactory and 52% found it good.

Whilst there were some challenging questions this year, the majority of candidates seemed to find the paper accessible and there were plenty of examples of excellent understanding of the material.

As in previous years, the most popular options were A (Mechanics) and H (Optics). The least popular were D (Medical) and E (Historical). However, options F and G continue to grow in popularity.
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 or 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). Whilst such an answer always gains full marks if correct, it is awarded zero if it is incorrect. 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 areas of the programme that proved difficult for the candidates

The manipulation of data (as opposed to substituting numbers into equations) caused problems for many candidates, particularly in respect of dealing with ratios (notably in D1 and F1)
Often, the impression gained from scripts is that candidates are using the equations given in the Data Booklet without thought.
The interpretation of graphical data and explanations of physical phenomena are beyond some candidates.

In this examination, the following topics proved difficult for many candidates:

- application of the principle of moments
- free body diagrams
- gravitational potential
- energy from nuclear fission
- scaling
- historical theories of electricity
- simultaneity
- relativistic mechanics
- the concept of focal point
- ray diagrams.

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

As in the past, answers based on routine definitions and calculations were often done well. However, some candidates demonstrated a good understanding of the option questions that they attempted and had obviously been well prepared for the examination. In particular, the Options B (Atomic and Nuclear), F (Astrophysics), and G (Special and General relativity) allowed the best candidates the opportunity to show their understanding of the principles involved.

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

Option A – Mechanics

Question 1 Forces acting on a bridge

(a) Whilst the mass of the bridge was, rather unrealistically perhaps, omitted from the question, most candidates managed to balance the forces.

(b) The application of the principle of moments to calculate the forces at the supports, was poorly answered by many candidates; the principle seemed to be unknown to them.

Question 2 Block on plane

Many candidates do not understand the term "free body diagram". The diagrams were often poorly drawn (no ruler used, for example or curved lines of indiscriminate lengths). Often there was a redrawing of the given diagram with block, slope, arrows and so forth, which was not required. Further, the vertical force (weight) was sometimes split, unnecessarily, into two components on the diagram. Many students still misunderstand the term "weight" as the description of a force vector, and instead mistakenly call it "gravity". Candidates should bear in mind the relative magnitude of each force: at the very least, the length of the vertical weight vector should exceed the length of the normal reaction and the friction force vectors.
Many candidates knew that they had to apply Newton's second law to calculate the acceleration but were unable to calculate the frictional force and hence the resultant force on the block. Good free body diagrams in part (a) usually led to good answers in part (b).
In the French paper, the weight of the block had been translated as "mass". At the Grade Award Meeting all French scripts were reviewed and only three candidates had multiplied the weight by 10. Of these three, one gained two more marks.

Question 3 Gravitation

The reading from the graph was generally done well although many candidates forgot to add the radius of the Earth for the satellite at 3.6 x 10^7 m above the Earth. However, many candidates resorted to calculations involving Newton's Law of Gravitation to calculate the energy, seemingly because they did not understand the purpose of the graph in part (a).
Not many candidates gave two clear and distinct reasons as to why only the minimum energy had been calculated. Answers were often vague referring to the inefficiency of the rocket motors. Few mentioned that, in order to go into orbit, the satellite needs to be given an initial horizontal velocity after reaching its orbital height.

Option B - Atomic and nuclear physics extension

Question 1 Photoelectric effect

Some candidates did not recognise that the value of *h* was the slope of the graph. Others took the ratio of one pair of points instead of the slope to find *h*. Several candidates used a data-book-value of *h* in (ii) to calculate the minimum energy *hf*, despite the question stating "use the graph to determine..."
The explanations as to the the existence of a threshold frequency were often weak and confused. A common error was to confuse the photoelectric effect with ionisation.

Question 2 X-rays

There were many wild guesses as to the labeling of the spectrum but the calculation of the maximum frequency was often done correctly.

Question 3 Radioactive decay and fundamental forces.

${}^{54}_{25}Mn$ decays to ${}^{54}_{24}Cr$ and not ${}^{54}_{24}Ar$ as in the question. However, this did not effect the validity of the question and most candidates answered correctly. Allowance was given for stating either neutrino or antineutrino.
Naming the exchange particles and the interaction was not done well.

Option C - Energy extension

Question 1 Nuclear energy

The first two parts of the question were generally answered well but a great many candidates had a fundamental misunderstanding of the role of the moderator, thinking that along with the control rods, its purpose is to prevent an uncontrolled chain reaction. The idea that neutrons have more chance of producing fission with the scarce ^{235}U if they are slower moving, would seem to be not known to them.

Question 2 Heat engine

Candidates do not always differentiate between the action verbs "state" and "explain". Most stated the answers to parts (a) (i) and (ii) correctly without explaining why. However, most correctly recognised the value of the total work done as the area enclosed by the graph and were also able to calculate the efficiency of the engine.

Option D - Biomedical physics

This Option was not popular, but more so than last year now that it has been reduced significantly in length. As last year, the question on scaling proved difficult.

Question 1 Scaling

This question caused immense difficulties, despite the fact that there is almost always a scaling question in Option D. Most candidates seem to rely on guesswork rather than on understanding.

Question 2 Ultrasound scanning.

Few candidates knew the correct range of frequency for ultrasound or why gel is used. Candidates who labelled the diagram correctly were able to correctly calculate the depth of the organ beneath the skin and also its length. However, quite a few candidates forgot to take into account the factor 2. Whereas most candidates knew about the advantages and disadvantages of using X-rays or ultrasound, few knew what a B scan is.

Option E – The history and development of physics

This was not a popular option. Too many answers lacked the required detail and were anecdotal rather than relying on principles of physics. There is a feeling amongst the examining team, that this option is often answered by candidates who clearly have made no study of the material covered by the option.

Question 1 Motion of Mars

A few candidates gave complete answers but many confused the models confused or offered incomplete answers. However, most knew about retrograde motion.

Question 2 Electrification by contact

It is appreciated that the diagrams could have been less ambiguous and as such any appropriate combination of G and E was allowed, with many of the candidates recognising that the events represented an attraction and repulsion. However, very few appreciated why Franklin called the two types of charge *positive* and *negative*; many just repeated the mantra, *like charges repel, unlike attract.*
Very few candidates made any sort of reasonable attempt at explaining attraction and repulsion in terms of Franklin's theory and in terms of the atomic theory. Accounts were

often confused with the two models mixed together and in many instances, it was clear that the candidate did not understand the question.

Question 3 Cathode rays

This question was generally very poorly answered. It is recognised that the names Goldstein and Perrin are not explicitly referred to in the syllabus but the importance of their work should be known. In this sense, the names are not essential to answering the question but do put the question in the correct historical setting. The general impression was that few candidates knew little about the early work on the discovery of the electron.

Option F – Astrophysics

This was a popular option and often answered well.

Question 1 H-R diagram and stellar distance

Many candidates gave correct, alternative labelling for the axes of the H-R diagram and were also able to identify the correct nature of the four stars.
It is appreciated that that the information given only enables one to deduce that star B is larger than star A, not more massive. However, there was no evidence to suggest that this confused candidates and the marking scheme was modified such that candidates who got as far as "larger", were given full credit. Having said this, many candidates correctly deduced the greater area of B from its luminosity and temperature and went on to say that therefore the mass would be greater. These candidates were of course, also given full credit.
As mentioned above, candidates who did not think to establish a ratio, had a great deal of difficulty in showing that star B is about 700 pc from Earth and often resorted to some very creative arithmetic. "Too far away" was not an acceptable answer as to why the distance of star B from Earth could not be determined by parallax.

Question 2 Evolution of the universe

This was often well answered with many completely correct answers. However, a common error was to use the >, = and < symbols without explicitly relating them to ρ_0 and ρ.

Option G - Special and general relativity

Question 1 Thought experiment

Although many candidates defined proper length correctly, there was much confusion with the definition of proper time. Some definitions were unclear, vague, approximate, incomplete or wrong. A typical wrong (confused definition) would be "time as measured in an inertial reference frame".
Most candidates suggested that the events would not be simultaneous for Carmen, indicating that event A will happen first. However, in the following explanation it was rarely stated that *c* is independent of the motion of the source or the observer, an essential fact in the argument. Many of the candidates also tended to jump from one frame to another thus seriously weakening the argument. At times the situation was over simplified and the subtleties of the concepts involved not appreciated. Some candidates incorrectly used the principle of causality to negate the possibility of non-simultaneity.
Using the equation for length contraction, many candidates calculated the speed correctly but some candidates did not identify the proper length. However, most candidates appreciated that neither observer could be considered to have the "correct" viewpoint.

Question 2 Relativistic electrons

The curve was generally well drawn, becoming asymptotic to the "c line". but a large number of candidates described the behaviour of the curve itself instead of using the principles of relativistic mechanics as suggested in the question. A few candidates briefly suggested the fact that the mass of the electron increases with speed, but did not elaborate.
The calculation of the electron mass and its total energy was sometimes done well but quite often was not started. Clearly, some candidates were familiar with these types of calculation and the others were not.

Option H – Optics

This is always a popular option but many candidates do not score well since they are unable to draw ray diagrams.

Question 1 Refraction

Many candidates gave a descriptive definition of refractive index ("how much light is bent"), ignoring that fact that definitions of physical quantities are operational. Symbols on diagrams or in equations were often not defined or wrongly defined and the requirement that the first medium be air or vacuum was also often ignored. Many candidates drew the "blue" ray successfully but the explanation was often absent or wrong or incomplete.

Question 2 Diverging lens

Very few candidates could give a correct definition of the focal point. Many candidates defined it as twice the radius of curvature of the lens, some others, as “the point where all light converges”.
Although the question stated in bold letters the words **concave (diverging)** to stipulate the lens, about 50% of all candidates treated this as convex. Although some credit was given, and ECF awarded if a converging situation was drawn, there was carelessness with this diagram (for example, in not noticing that two rays emanated from the top of the object, and two rays from the base of the object). As stated last year, if candidates are to score well in this option, they must be able to construct meaningful ray diagrams.
Calculating the magnification caused few difficulties but suggesting as to what might happen in part of the lens were covered gave rise to a lot of interesting speculation.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team included the following ideas:

- Candidates should read the question paper through before starting, not only to gauge the variety of questions but also the number of sections in each question and the difficulty before choosing and starting.
- Candidates should read each question carefully and focus their answers accordingly.
- More practice is needed with the interpretation of data – particularly when the data is presented in graphical or tabular form
- Practice with the manipulation of ratios both in numeric and in symbolic form.
- It is important that Options are not left until the end of the course. This can lead to their study being rushed or incomplete. The time available for the study of the Options should be allowed

for and carefully integrated into the programme as a whole. Candidates should not attempt to answer an Option that they have not studied.

- If candidates study an Option on their own, then teachers should ensure that their progress is carefully monitored and that adequate support is given. Students from a school that answered questions in the same two options generally performed better than those that answered questions from several different options.

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-14	15-22	23-29	30-35	36-42	43-60

The G2 feedback forms submitted after the examination contained both praise and constructive criticism. The critical comments were taken into careful consideration during the grade award process in making judgements about the overall level of difficulty and the likely effect of particular questions on candidates. The process of setting grade boundaries is responsive to teacher feedback and teachers are urged to submit their comments (if they have any) on the form G2. The feedback can be summarized as follows:

- about 60% found the paper to be of a similar standard to last year and 40% a little more difficult. However, overall, 92% found the paper to be of an appropriate standard and 8% thought it too difficult.
- about 53 % found the syllabus coverage satisfactory and 47 % good
- about 53% found the clarity of wording satisfactory and 47% found it good
- about 47% found the presentation satisfactory and 48 % found it good and 5% found it poor.

Whilst there were some challenging questions this year, the majority of candidates seemed to find the paper accessible and there were plenty of examples of excellent understanding of the material.

As in previous years, the most popular options were F (Astrophysics) and H (Optics). The least popular were D (Medical) and E (Historical). However, G continues to grow in popularity.
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 or 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). Whilst such an answer always gains full marks if correct, it is awarded zero if it is incorrect. 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 areas of the programme that proved difficult for the candidates

The manipulation of data (as opposed to substituting numbers into equations) caused problems for many candidates, particularly in respect of dealing with ratios (notably in D1 and F1).
Often, the impression gained from scripts is that candidates are using the equations given in the Data Booklet without thought.
The interpretation of graphical data and explanations of physical phenomena are beyond some candidates.

In this examination, the following topics proved difficult for many candidates:

- scaling
- historical theories of electricity
- Bohr theory
- simultaneity
- relativistic mechanics
- the concept of focal point
- ray diagrams
- single slit diffraction and optical resolution.

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

As in the past, answers based on routine definitions and calculations were often done well. However, some candidates demonstrated a good understanding of the option questions that they attempted and had obviously been well prepared for the examination. In particular, the options F (Astrophysics) and G (Special and General relativity) allowed the best candidates the opportunity to show their understanding of the principles involved.

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

In Options D, E, F, G and H many comments appertaining to HL candidates also apply to SL candidates.

Option D - Biomedical physics

This Option was not popular, but more so than last year now that it has been reduced significantly in length. As last year, the question on scaling proved difficult.

Question 1 Scaling

This question caused immense difficulties, despite the fact that there is almost always a scaling question in Option D. Most candidates seem to rely on guesswork rather than on understanding.

Question 2 Ultrasound scanning

Few candidates knew the correct range of frequency for ultrasound or why gel is used. Candidates who labelled the diagram correctly were able to correctly calculate the depth of the organ beneath the skin and also its length. However, quite a few candidates forgot to take into account the factor 2. Whereas most candidates knew about the advantages and disadvantages of using X-rays or ultrasound, few knew what a B scan is.

Question 3 Energy from food

Most candidates had no trouble with this question.

Question 4 Radiation in medicine

This was generally poorly answered. Very few candidates could give correct definitions of exposure and absorbed dose or relate the terms to α and γ radiation. It was also clear that the distinction between biological and physical half-life was not known well.

Option E – The history and development of physics

This was not a popular option. Too many answers lacked the required detail and were anecdotal rather than relying on principles of physics. There is a feeling amongst the examining team, that this option is often answered by candidates who clearly have made no study of the material covered by the option.

Question 1 Motion of Mars

A few candidates gave complete answers but many confused the models or offered incomplete answers. However, most knew about retrograde motion.

Question 2 Electrification by contact

It is appreciated that the diagrams could have been less ambiguous and as such any appropriate combination of G and E was allowed, with many of the candidates recognising that the events represented an attraction and repulsion. However, very few appreciated why Franklin called the two types of charge *positive* and *negative*; many just repeated the mantra, *like charges repel, unlike attract.*
Very few candidates made any sort of reasonable attempt at explaining attraction and repulsion in terms of Franklin's theory and in terms of the atomic theory. Accounts were often confused with the two models mixed together and in many instances, it was clear that the candidate did not understand the question.

Question 3 Cathode rays

This question was generally very poorly answered. It is recognised that the names Goldstein and Perrin are not explicitly referred to in the syllabus but the importance of their work should be known. In this sense, the names are not essential to answering the question but do put the question in the correct historical setting. The general impression was that few candidates knew little about the early work on the discovery of the electron.

Question 4 The hydrogen atom

This was generally not well answered. Few candidates appeared to know that an electron in a Bohr orbit does not radiate energy. A large number of candidates interpreted *m* in the Rydberg equation as the mass of the electron and so missed this part of the question completely. Most candidates had some idea of the electron cloud and the probabilistic interpretation of the Schrodinger wavefunction.

Option F – Astrophysics

This was a popular option and often answered well.

Question 1 H-R diagram and stellar distance

Many candidates gave correct, alternative labelling for the axes of the H-R diagram and were also able to identify the correct nature of the four stars.
It is appreciated that that the information given only enables one to deduce that star B is larger than star A, not more massive. However, there was no evidence to suggest that this confused candidates and the marking scheme was modified such that candidates who got as far as "larger", where given full credit. Having said this, many candidates correctly deduced the greater area of B from its luminosity and temperature and went on to say that therefore the mass would be greater. These candidates were of course, also given full credit.
As mentioned above, candidates who did not think to establish a ratio, had a great deal of difficulty in showing that star B is about 700 pc from Earth and often resorted to some very creative arithmetic. "Too far away" was not an acceptable answer as to why the distance of star B from Earth could not be determined by parallax.

Question F2 Evolution of the universe

This was often well answered with many completely correct answers. However, a common error was to use the >, = and < symbols without explicitly relating them to ρ_0 and ρ.

Question F3 White dwarfs and neutron stars

This was generally well answered although some candidates got tied up in trying to explain the difference between a white dwarf and neutron star.

Question 4 Redshift, Hubble and the age of the universe

Quite a few candidates did not draw a straight line that went through the origin and a substantial number had difficulty with the calculation of the age of the universe, particularly with the units.

Option G - Relativity

Question 1 Thought experiment

Although many candidates defined proper length correctly, there was much confusion with he definition of proper time. Some definitions were unclear, vague, approximate, ncomplete or wrong. A typical wrong (confused definition) would be "time as measured in an inertial reference frame".
Most candidates suggested that the events would not be simultaneous for Carmen, indicating that event A will happen first. However, in the following explanation it was rarely stated that *c* is independent of the motion of the source or the observer, an essential fact in the argument. Many of the candidates also tended to jump from one frame to another thus seriously weakening the argument. At times the situation was over simplified and the subtleties of the concepts involved not appreciated. Some candidates incorrectly used the principle of causality to negate the possibility of non-simultaneity.

Using the equation for length contraction, many candidates calculated the speed correctly but some candidates did not identify the proper length. However, most candidates appreciated that neither observer could be considered to have the "correct" viewpoint.

Question 2 Relativistic electrons

The curve was generally well drawn, becoming asymptotic to the "c line". but a large number of candidates described the behaviour of the curve itself instead of using the principles of relativistic mechanics as suggested in the question. A few candidates briefly suggested the fact that the mass of the electron increases with speed, but did not elaborate.The calculation of the electron mass and its total energy was sometimes done well but quite often was not started. Clearly, some candidates were familiar with these types of calculation and the others were not.

Question 3 Spacetime, gravity and black holes

It is recognised that spacetime diagrams are not on the syllabus as such but it also recognised that they are a very useful concept. In this question, the diagram was meant to aid the candidates with their answer. However, it would probably have been preferable to let the candidates choose their own way to answer the question. Needless to say, full credit was given for a verbal description irrespective of what or whether a diagram was drawn.
Answers in terms of the warping of spacetime were generally sound and it should be noted that a non-relativistic description of a black hole was given credit.

Option H – Optics

This is always a popular option but many candidates do not score well since they are unable to draw ray diagrams.

Question 1 Refraction

Many candidates gave a descriptive definition of refractive index ("how much light is bent"), ignoring that fact that definitions of physical quantities are operational. Symbols on diagrams or in equations were often not defined or wrongly defined and the requirement that the first medium be air or vacuum was also often ignored. Many candidates drew the "blue" ray successfully but the explanation was often absent or wrong or incomplete.

Question 2 Diverging lens

Very few candidates could give a correct definition of the focal point. Many candidates defined it as twice the radius of curvature of the lens, some others, as "the point where all light converges".
Although the question stated in bold letters the words **concave (diverging)** to stipulate the lens, about 50% of all candidates treated this as convex. Although some credit was given, and ECF awarded if a converging situation was drawn, there was carelessness with this diagram (for example, in not noticing that two rays emanated from the top of the object, and two rays from the base of the object). As stated last year, if candidates are to score well in this option, they must be able to construct meaningful ray diagrams.
Calculating the magnification caused few difficulties but suggesting as to what might happen in part of the lens were covered, gave rise to a lot of interesting speculation.

Question 3 Single slit diffraction

It should be noted that the term "Fraunhofer diffraction" is used in the Subject Guide and the term was used in this question to alert the candidates to the fact that the question dealt with plane wavefronts. There was nothing in the candidates' answers to suggest that the use of the term had disadvantaged them; weak answers were clearly due to lack of knowledge and understanding of the topic. Many candidates failed to mention that it is the interference of the waves originating from the various different points on the incident wavefront that accounted for the diffraction pattern. However sketches of the intensity distribution were generally done well but the statement of the Rayleigh criterion and its application caused a lot of problems.

Recommendations and guidance that teachers should provide for future candidates

Recommendations from the examination team included the following ideas:

- Candidates should read the question paper through before starting, not only to gauge the variety of questions but also the number of sections in each question and the difficulty before choosing and starting.
- Candidates should read each question carefully and focus their answers accordingly.
- More practice is needed with the interpretation of data – particularly when the data is presented in graphical or tabular form
- practice with the manipulation of ratios both in numeric and in symbolic form.
- It is important that Options are not left until the end of the course. This can lead to their study being rushed or incomplete. The time available for the study of the Options should be allowed for and carefully integrated into the programme as a whole. Candidates should not attempt to answer an Option that they have not studied.
- If candidates study an Option on their own, then teachers should ensure that their progress is carefully monitored and that adequate support is given. Students from a school that answered questions in the same two options generally performed better than those that answered questions from several different options.

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

Range and suitability of work

There were a number of schools demonstrating a rich and diverse program of experimental work. These schools had a variety of investigations, covering the entire syllabus including options. They also gave the student plenty of opportunity to be assessed on the various criteria. There was also an increased number of open-ended investigations, specifically designed for student planning. This is an encouraging sign that the IB curriculum is influencing teachers. On the more critical side, the topic of mechanics, as always, was often over emphasized, and many schools had little or no investigations in the options or extension material, with the exception of the Optics topic. Most schools managed something reasonable for their group 4 projects. Finally, it was not uncommon to find a school using investigations that were not syllabus based, such as simple harmonic motion, capacitors, and other traditional topics; these worked well for assessment.

A few schools are still assigning worksheets that give the student a fill-in-the-blank approach to experimental work. This may work well in a class but it is not appropriate for criteria based assessment. Computer data sampling is also common, and teachers must be careful in deciding whether the software being used is suitable when assessing data collection. See FAQ on OCC for guidance. The student must decide what data is collected and how it is to be presented. Students often work in teams, and this is fine, but the resulting work is not always appropriate for internal assessment.

Performance against each criterion

When commenting about student performance against IA criteria we must distinguish the role of the teacher and the achievement of the student. For a student to achieve high marks for a given criterion, the student must not only know some good physics but the teacher must also set a relevant context in which the student can achieve high marks.

Planning (a)

This remains one of the most difficult points to get over to teachers. To ask a student to confirm Ohm's Law already gives them a research question, the hypothesis, and the variables are written in the equation. And yet this is typical of some of the investigations that were used to assess planning (a). Planning (a) investigations need to be open-ended, where the student defines a question and follows through. If all the students in the class do the same thing then the assignment was not open-ended. Teachers should see IBCA's Online Curriculum Center for details under the teacher support material. It was encouraging to see many schools assigning appropriate planning investigations. The problems in this area were far less than in previous years.

Planning (b)

The appropriateness of this criterion follows closely to the planning (a) criterion. If planning (b) is appropriate then students should not all do the same thing. Although classroom equipment is limited, there is room for different approaches and different techniques, and this variety should be revealed in planning (b) exercises. Overall, planning (b) received better marks than planning (a). Teachers need to appreciate the detailed aspects under the planning (b) criterion. Here, students select the equipment and materials, then students design a method to carry out the investigation. If the teacher hands out voltmeters and ammeters and standard resistors, there is no room for student contributions to the planning (b) aspects of the investigation. Teacher should note that there are a number of planning (a) and (b) exercises that can be assigned and no follow though is required. That is, students can do a planning exercise but not actually perform the experiment.

Data Collection

This is the easiest criterion to earn high marks on, but students and teachers still need to be careful here. All experimental measurements involve a minimal amount of uncertainty, if no more than the one number in the least significant digit. This uncertainty must be recorded with all raw data, and in most cases there are more uncertainties that can be addressed. Only higher-level students need to process uncertainties (where relevant), but both standard and higher students need to recognize them and record them correctly with the raw data. Units, of course, must be recorded with uncertainties, and units must also be given with the raw data. Just because the stopwatch reads seconds does not mean that recorded data is in seconds. Students need to design and complete their own data tables, and where the teacher gives them this information, assessment is no longer relevant. Moderation then takes marks down. Overall, this criterion was successfully addressed. Most teachers realize that when some computer interfaces collect data, that the data and its presentation are not suitable for assessing data collection.

Data processing and presentation

Students must not be told to draw a graph of x against y, or how to process the data. When this is done, moderators lower the marks. Students must decide what quantities to process mathematically and then what quantities to graph (and of course what to do with the graph). In some cases there is very little or even no processing in the sense of a mathematical calculation. For example, if raw data consists of the drop height and rebound height of a ball, then processing would be interpreted as reproducing the data correctly on a graph, perhaps a graph of rebound against drop heights. In this example, standard level student would be able to construct uncertainty bars on the rebound heights on the graph. In more complicated examples, processing might consist of taking the sine function of measured angles, or calculating momentum from raw data measurements. Many students are using computer programs to draw graphs, and this is fine. But when the computer generates uncertainty bars as a default (and there is no student justification or calculation in the text) then it is clear to the moderator that this does not count as an appreciation of uncertainty. Also, connecting the points, dot-to-dot, is usually not relevant to physical relationships. Students must be in control of the graphing program to obtain satisfactory results in IA under DPP. Finally, significant digits are often misused in graphing programs. This needs to be addressed by students, as well an correctly appreciating the slope of graphs (with units, when appropriate).

Conclusion and evaluation

It is difficult to satisfy all the aspects of this criterion. Students are often so enthusiastic that they just write judgmental comments such as how much they enjoyed the investigation and that it worked well. In such cases, students need to be reminded of the three aspects of the CE criterion. Teachers need to be reminded of this too when assessing the conclusion. Good planning (a) helps define what needs to be said in the conclusion.

Recommendations

The teacher must carefully choose investigation for IA. This is the most important recommendation. Many labs can be carried out in class and not used to IB assessment, but when it comes to assessment, labs must be relevant otherwise marks will be lost.

When submitting student work and 4/PSOW forms, teachers must carefully follow instructions and mark the work as required. Most schools do this but there are some that have not read the instructions.

It is vital to submit a copy of the instruction given to students for the work that is being moderated. Even if it was verbal, the teacher needs to spell this out to the moderator so the moderator knows the context in which the student did the work.

Students need more guidance with how to deal with errors and uncertainties. They also need more guidance with constructing graphs.

If two or more teachers are involved in teaching the assessment of investigations, then it is crucial that they work together to moderate internally before any samples are sent to the moderator.

Teachers should visit the On Line Curriculum Centre for teacher support material on internal assessment. Phase 1 has guidance on Planning experiments, personal and manipulative skills and errors and uncertainties. Phase 2 has examples of marked experiments. Moderators will be taking the guidance given here into account when assessing work for the May 2004 examination session onwards.

Comments

The majority of schools are doing an admirable job, covering the syllabus with interesting and relevant investigations. The majority of schools realize that not all criteria fit all experiments, and that many experiments can be done and no IA marks need to given. Also encouraging is that many schools are appreciating the open-ended nature of planning (a) and planning (b). Many schools are using a homemade IA based mark schemes when assessing student work. This helps the teacher, the student, and the moderator when it comes to moderation. Overall, most marks teacher gave their students were acceptable. In a few cases, teachers were too severe and moderators raised marks; in more cases, moderators lowered marks. Occasionally the teacher was too lenient here, but the major reason for lowering marks was that the teacher assigned inappropriate work, work that did not allow the IA criteria to be fulfilled.

