PHYSICS (IBAEM/IBAP)

To improve the security of IB examinations, a selection of examination papers now have regional variants, including physics HL and SL papers 1, 2 and 3. The following report is for *physics* taken by candidates in the IB regions of Africa, Europe, the Middle East and Asia/Pacific.

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-28	29-39	40-50	51-62	63-73	74-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-27	28-39	40-50	51-61	62-72	73-100

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

It would seem that more Schools than last year are producing imaginative, well-balanced programmes that give good syllabus coverage both of the Core and the Options and which also expose the candidates to a wide range of experimental techniques. These schools demonstrate that good experiments can be designed using simple equipment. However, some schools' programmes continue to be dominated by experiments in mechanics at the expense of the other parts of the syllabus.

In some cases very little knowledge was displayed of the various measurement techniques available in experimental work or of the different analytical techniques available for dealing with data. Some candidates found graphical analysis difficult and often used incorrect, computer generated graphs.

Fewer schools than in previous years made extensive use of worksheets, but there was still a tendency to overdo computer sampling at the expense of more traditional methods of obtaining data.

In the respect of worksheets, if a worksheet gives all the instructions necessary to assemble the apparatus for a particular experiment and also tells the candidates what readings of which quantities they should take, then this experiment cannot be used for the assessment of Planning skills.

Students should also be taught the correct application of error analysis and also how to make a quantitative evaluation of a particular experiment. For example, a candidate who carries out an experiment to measure g and comes up with a value 9.73 m s-1 and then writes something to the effect " the actual value of g is 9.81 m s-2 so therefore there is an error in my result of x%, so all in all this has been successful experiment", clearly has no idea of the correct way to assess errors or how to make a quantitative evaluation of procedure.

Candidate performance against each criterion.

Planning (a) and Planning (b)

Students often do not perform well with Planning skills. This is often due to the type of experiments that some teachers submit as evidence of assessment of the Planning criteria.

For assessing Planning, teachers need to give the candidates more open-ended tasks. For example instead of just giving them instructions to measure that acceleration due to gravity using a simple pendulum, the candidates can be asked to investigate the factors (or one factor) that affect the period of a simple pendulum. In such an experiment the candidates have to identify the factor(s), hypothesise as to the possible outcome, identify the variables to control and then design a suitable method to carry out the investigation. Experiments that are designed to measure a specific quantity or that set out to verify a physical law or relationship do not allow candidates to formulate a research question or hypothesis and in most cases, the variables are prescribed. For example, experiments such as "To measure the wavelength of laser light" or "to verify Snell's law" do not lend themselves to the assessment of planning skills.

If candidates are given too much information about an experiment in respect of the apparatus, methods and procedures to use, or if they are directed to a reference that gives an account of the experiment, that then this experiment cannot be used to assess Planning (b). Students must choose the apparatus and decide for themselves, the method and procedures to use. This also means that they must work on their own and as such, means that the Group 4 Project is not usually suitable for assessing either of the Planning criteria or for that matter, Data Collection.

For the moderator to make an accurate assessment of the teacher marking of the Planning Criteria, it is essential that a copy of the instructions given to the candidates is enclosed with the sample material. In fact the moderator will not start to mark any of the sample material until such a copy is obtained from the school.

Data collection

This is usually well done except in some cases where data is very poorly presented. The data should, where appropriate, be put into a table and units and uncertainties should be included. Students should be taught that every measurement that they make involves an uncertainty! Also, if candidates are given a headed table on a worksheet as part of an experiment, then this experiment cannot be used to assess data collection. Also, it should be born in mind that experiments such as plotting magnetic field lines are not suitable for assessing this criterion. For Physics, the experiment should involve the collection of quantitative raw data.

Data Processing and Presentation

This was often poor. Students should be taught how to transform their data into a form that makes for good graphical analysis. The concept of error bars would appear to be alien to many candidates If candidates are told how to present the data, then they cannot gain a complete on the second aspect of this criterion. Too often one sees the instruction given to candidates "plot a graph of … against …."
Students rely too often, on computer graphing without clearly understanding what they are doing . They are the under the impression that if the computer gives them an equation for their graph, the regression and error bars, then this is good data presentation. In respect of error bars on computer generated graphs, the candidate must make it clear to the moderator, the basis upon which the error bars have been generated.

When graphical analysis is not involved, candidates still lost marks through poor, and in some instances, incomprehensible presentation of their data.

Again, experiments used to assess this criterion, should involve quantitative data.

Conclusion and Evaluation

This was often weak. In many cases, the conclusion was omitted and rarely was the problem of the limitations of a particular technique addressed. Furthermore, candidates rarely suggested possible improvements to the experiments or identified any possible weakness in the techniques used. The idea of repeating the readings as an improvement to the experiment, is often missed.

The recommendations for the teaching of future candidates.

The recommendations are essentially given above. However, to summarise:

- Choose appropriate experiments to assess correctly, the respective criteria
- Include the instructions given to the candidate for each experiment including a summary of any verbal instructions
- Get candidates to present data neatly, (use a ruler to draw tables) include units and uncertainties
- Make sure that candidates become familiar with graphical analysis techniques and present any analyis in a neat and logical manner
- Make sure that candidates always present a definite conclusion, assess limitations of the techniques used and suggest ways of improving the experiment.
- For the assessment of Pl(a), Pl(b) and DC, candidates should ideally work individually. If the candidates work in a group, then the individual work of the candidate must be identified in the work submitted for moderation
- DPP and CE must be individual work
- If two or more teachers are involved in the assessment of IA, then it is imperative that the work is moderated internally before any samples are sent to the moderator.

Teachers are strongly advised to note the guidance in the online Teacher Support Material phases 1 and 2 available on the Online Curriculum Centre (OCC) when setting and assessing practical work for the Group 4 Internal Assessment Scheme. Internal Assessment moderators will, in future be taking this guidance into account in their moderation of IA sample work from schools.

This year most 4/PSOW forms were completed correctly by the teachers but some schools are still sending complete portfolios of all the candidates in the sample and others, one complete portfolio.

Paper 1

Component grade boundaries

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

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-14	15-17	18-20	21-23	24-30

General comments

IB multiple choice physics papers are designed to have, in the main, questions testing 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 2004 Papers 1 were generally well received. Nearly all of the teachers who commented on the Papers felt that they contained questions of an appropriate level. A small number thought that the SL Paper was a little more difficult. With few exceptions, teachers thought that the Papers gave satisfactory or good coverage of the syllabus. However, coverage should be judged in conjunction with Paper 2. All teachers also felt that the presentation of the Papers was either satisfactory or good. However, a few teachers felt that the wording of a small number of questions in the HL Paper could have been improved.

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	114	441	1169*	176	5	61	.28
2	253	651*	557	437	7	34	.25
3	452	363	836*	250	4	44	.42
4	990*	204	302	406	3	52	.45
5	133	1674*	34	63	1	88	.27
6	77	199	428	1201*		63	.56
7	204	1207	222	267*	5	14	.23
8	117	238	218	1330*	2	70	.43
9	198	464	305	935*	3	49	.29
10	160	1648*	25	70	2	87	.20
11	357	311	1100*	124	13	58	.54
12	621*	796	254	228	6	33	.18
13	1066*	246	442	144	7	56	.48
14	54	24	169	1653*	5	87	.21
15	86	138	1309*	371	1	69	.30
16	536*	221	113	1034	1	28	.22
17	1510*	84	175	135	1	79	.28
18	21	193	20	1670*	1	88	.25
19	1022*	333	308	236	6	54	.49
20	509	128	1173*	93	2	62	.48
21	183	1492*	149	78	3	78	.28
22	1618*	156	65	64	2	85	.33
23	60	1387*	30	425	3	73	.21
24	738	101	176	885*	5	46	.38
25	786*	356	452	287	24	41	.29
26	119	249	237	1293*	7	68	.49
27	557	787*	361	182	18	41	.44
28	242	341	1095*	201	26	57	.53
29	1177*	334	174	210	10	62	.57
30	410	249	1178*	52	16	62	.45

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	122	480	1500*	185	5	65	.20
2	257	186	1700*	140	9	74	.45
3	307	214	1693*	75	3	74	.34
4	1037*	1061	187		7	45	.43
5	302	480	1295*	203	12	57	.41
6	49	2149*	39	52	3	94	.13
7	38	98	283	1870*	3	82	.35
8	145	545	239	1352*	11	59	.35
9	112	2094*	13	69	4	91	.14
10	1097*	789	227	167	12	48	.32
11	395	134	1661*	100	2	72	.33
12	750*	847	636	55	4	33	.41
13	374	1251*	376	282	9	55	.57
14	670	1078*	337	198	9	47	.35
15	63	141	1796*	291	1	78	.25
16	873*	269	121	1023	6	38	.34
17	1935*	67	139	147	4	84	.11
18	88	617	37	1550*		68	.35
19	1721*	115	401	52	3	75	.38
20	302	258	1635*	93	4	71	.33
21	5	169	8	2110*		92	.13
22	154	1973*	107	58		86	.20
23	1587*	202	370	125	8	69	.35
24	245	38	1717*	289	3	75	.39
25	212	158	1424*	489	9	62	.44
26	37	1866*	14	373	2	81	.19
27	1117	134	148	891*	2	39	.29
28	411	1360*	351	159	11	59	.54
29	236	1138*	638	272	8	50	.44
30	1172*	428	356	306	30	51	.37
31	272	195	81	1731*	13	76	.41
32	34	113	1380*	751	14	60	.48
33	1091*	1128	56	14	3	48	.39
34	1024*	360	258	631	19	45	.51
35	644	1142*	280	221	5	50	.40
36	241	407	1186	440*	18	19	.25
37	343	1082*	296	559	12	47	.40
38	215	391	1446*	209	31	63	.52
39	248	362	1215*	457	10	53	.51
40	810*	283	977	214	8	35	.22

In Q4 above, A and D were both marked correct with 1037 correct answers.

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 comments 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.

Standard level and common questions

Standard level question 3

The expression "zero offset error" was used with the intention of helping the candidate with the wording. High discrimination index with a lot of guessing at both levels.

Higher level question 5, standard level question 3

The expression "zero offset error" was used with the intention of helping the candidate with the wording. High discrimination index with a lot of guessing at both levels.

Higher level question 7, standard level question 6

High discrimination index at both levels. Possibly a lack of familiarity with acceleration vs time graphs explains the lower percentage of success for SL candidates.

Higher level question 8, standard level question 9

A significant number of candidates (25%) chose answer B instead of the correct answer D. Possibly these candidates considered (incorrectly) that conservation of momentum implies automatically conservation of energy.

Higher level question 9, standard level question 10

In the French version, the word "vitesse" is used. Since "impulsion" is a vector, it is implicit that the intent here is "vecteur vitesse", not the scalar "vitesse". In the English version the word "velocity" refers to a vector.

Higher level question 10, standard level question 12

The question refers to a classic set-up. High discrimination index for HL candidates and high difficulty index for SL candidates. In both cases, the most "popular" choice of the wrong answer B indicates that many could calculate the net force but forgot to apply it to both masses (m or M). In the French version, the use of the expression “l’accélération gravitationnelle” was unfortunate, but in this context, it would not adversely affect the result.

Standard level question 13

Almost 1 candidate out of 4 chose answer C, not realising that this answer, unit wise, is not possible.

Higher level and standard level question 16

The popularity of answer D as a choice indicates that many candidates misread the expression “real gases”

Standard level question 20

1 candidate out of 4 chose answer A apparently having not given attention to the fact that the Doppler effect is not about loudness of sound.

Standard level question 24

Almost 40% of the candidates chose A rather than D. This fact suggests that the connection of the unit coulomb with the operational definition of the ampère was not made.

Standard level question 25

A lot of guessing by the candidates who considered this question somewhat challenging. The design of the Paper is such that each and all of the questions will not carry the same level of difficulty and discrimination.

Higher level question 28, standard level question 27

High discrimination index at both levels. A significant number of candidates did not realise that the magnetic force is not a function of the mass of the charged particle.

Higher level

Higher level question 4

A general answer was looked for but the specific angle between the two vectors F (120°) on the sketch made it possible for the answers A and D to be plausible. Both answers were accepted. The large number of choices for answer B indicates that nearly 50% of candidates did not take into account the vector nature of F and W.

Higher level question 13

High discrimination index with a lot of guessing, considering the broad choice of answers chosen.

Higher level question 19

It is implicit that the question is about the work done in one cycle. In hindsight, it would have been better to include this detail. The choices of answers by the candidates did not indicate that this was actually a problem.

Higher level question 33

Nearly half of the candidates blindly applied the definition of magnetic flux linkage without giving proper attention to the role of q in yielding the component of B perpendicular to the area S.

Examiner comment

In general, conceptual questions of the type used in these multiple choice papers demand good understanding of basic definitions, concepts and principles, often more so than quantitative formula-based problems. They require insight into situations and the ability to apply quality 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. At Higher Level, 11 questions carried a "facility index" below 50%. Five of these questions involved a definition and two were related to free body diagrams and the application of Newton's laws of motion. At Standard Level, 9 questions carried a "facility index" below 50%. Four of these questions involved a definition. Nevertheless, it is encouraging that many candidates scored high marks and demonstrated good preparation for the examination.

The relative distribution of the choices of the candidates among the proposed answers A to D can reveal key conceptual difficulties encountered by the candidates. Such information could be highly useful in the teaching of particular concepts or definitions. Also the difficulty and discrimination indices could be useful to a teacher designing multiple choice tests.

Paper 2

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-12	13-24	25-35	36-46	47-58	59-69	70-95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-18	19-24	25-30	31-36	37-50

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 85% found the papers to be of a similar standard to last year, 5% a little easier, 13% a little more difficult and 7% much more difficult.

- About 95% found the level of difficulty appropriate and about 5% too difficult.
- About 56% found the syllabus coverage good, 40% satisfactory and 4% poor.
- About 60% found the clarity of wording satisfactory, and 20% found it good.
- About 80% found the presentation good, and 20% found it satisfactory.

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.

As last year 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" (ECF) marks. However, some candidates still, as in previous years, continue not to show their working and so lose partial marks when the answer that they write down is incorrect. There was a general feeling that candidates were taking more care with diagrams than in past years.

The areas of the programme that proved difficult for the candidates

Higher level and standard level

As in previous years, 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:

- Definition of resistance
- Recognition of the nature of centripetal force and associated problems
- Use of Huygen's principle
- Definition of binding energy and use of the binding energy curve.

Higher level only

In the Higher Level examination the following topics proved difficult for many candidates:

- Induced emf's
- Electrostatic potential of a charged sphere
- Static equilibrium and moments
- Entropy and the 2nd law
- Atomic energy levels

Standard level only

In the Standard level examination the topics of vector addition and problems associated with electric fields proved difficult for many candidates.

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

Higher level and standard level

Generally there was good knowledge of formulae and their application to the solving of numerical problems. In general, many candidates seemed to be well prepared in respect of the following topics:

- Graph plotting
- Momentum conservation
- Basic wave properties
- Nuclear equations

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

Section A

Higher level question 1: Data analysis

Many candidates gained full credit for the graph plotting. However, a significant number of candidates did not know how to draw the line with the maximum permissible gradient and also, often chose points too close together to find a realistic value of the gradient. As with SL candidates, few candidates gave the correct unit for capacitance and many had difficulty in using the gradient to find the permittivity of free space. Nevertheless, there were some excellent answers to the question as a whole.

Standard level question 1: Data analysis

Many candidates gained full credit for the graph plotting and the drawing of the best fit line. However, a significant number of candidates chose points too close together to find a realistic value for the gradient.

Few candidates gave the correct unit for capacitance and many had difficulty in using the gradient to find the permittivity of free space. Nevertheless, there were some excellent answers to the question as a whole.

Higher and standard level question 2: Colliding trucks

This was often well answered. Some candidates did not define momentum but instead attempted to give a qualitative description. A significant number of candidates talked about "lost" rather than "transformed" energy.

Higher and standard level question 3: The filament lamp

The most common error was for candidates to draw a linear characteristic or to draw a characteristic consistent with V on the x-axis. Many candidates thought that the resistance was obtained by finding the slope of the graph. This is true, of course, for ohmic conductors, and so they could obtain an ECF mark here. However, candidates should be discouraged from this approach. Explanations as to whether the behaviour was ohmic were often missing.

Higher level question 4: Induced emf

This question, designed to illustrate the conversion of mechanical power into electrical power, proved difficult for a lot of candidates. Many were unable to correctly show the directions of FE and FM or show that the mechanical power was equal to the electrical power dissipated in the rod.

Section B

Higher and standard level question 1 part 1: Circular motion

It is interesting to note that the question concerned with explaining acceleration at constant speed has been set, in one form or another, several times before and that over the years the quality of the answers has improved significantly. In this exam, it was therefore pleasing to note that many candidates gave clear and accurate explanations of this phenomenon. However, the same cannot be said about the understanding of the nature of centripetal force. When asked to identify the two forces acting on the marble, the most common answer was "weight and centripetal force". This meant that there was little chance of these candidates successfully determining the reaction force acting on the marble.

The calculation of the value of the speed was done well by many candidates. It was appreciated that, due to rotational energy, the speed would be closer to 2.0 ms^{-1} and that perhaps it might have been better, in terms of the physics, to have had a small metal block sliding without friction down the ramp.

Higher level part 2: Charged sphere

Definitions of electric potential were often incomplete and although many candidates drew correct equipotentials they were unable to explain why they showed that the field was decreasing. Generally the variation of potential with distance from the centre of the sphere was not known and many struggled with the calculation.

Standard level part 2: Charged sphere

The only parts of this question that were answered with any confidence by the majority of candidates were the sketching of the field pattern and the calculation of the field strength. Some candidates appreciated that the electron would follow a field line and some appreciated why the acceleration of the electron would decrease as it moved away from the sphere but few could use the speed of the electron to calculate the potential difference.

Question 2

Higher level part 1: Static equilibrium

Diagrams of the forces were often well done and although knowledge of cotangent is not a mathematical requirement, many candidates were familiar with it or assumed it from their correct taking of moments.

Although there were some excellent answers to the ladder problem, many candidates failed because clearly they had very poor knowledge of the conditions for static equilibrium. Although many candidates knew instinctively that the height should be increased, few could give a coherent argument.

Standard level part 1: The solenoid

The field pattern of the solenoid was often well drawn but few recognised that a bar magnet would produce a similar pattern. Many merely stated "magnet", perhaps expecting the examiner to realise that they meant "bar magnet".

The vector addition of the fields defeated most candidates.

Higher and standard level part 2: Refraction

Most candidates were able to correctly draw the position of the wavefront and identify the relevant distances. However, there was widespread difficulty with the proof, with many candidates leaving this blank. A common incorrect approach, not using the diagram, was to use Snell's law and the equation $n = \frac{c}{v}$.

The calculations were often done well.

Question 3

Higher and standard level part 1: Nuclear binding energy

Definitions of nuclear binding energy were often poor and could not really be classed as definitions e.g. "nuclear binding energy is the energy that binds the nucleus together".

In the French version of the paper, nucleon number was translated as atomic number. This was taken into account and did not seem to have affected the candidates, with many ignoring the mistranslation. According to the Subject Guide, it is expected that candidates should be able to draw and annotate the nuclear binding energy curve. In this respect, they should have knowledge of the values of the three main binding energies associated with the curve, in fact, the three values asked for in the question. A degree of latitude was allowed and a significant number of candidates gave values within this range. Those who gave values outside this range often gained ECF marks when drawing the associated graph. Use of the graph to explain the release of energy in the fusion of deuterium was seldom convincing.

Higher level part 2: Wave interference

The principle of superposition was often stated in terms of the sum of amplitudes instead of displacements. Also, not many candidates appreciated that narrow slits ensure overlapping wavefronts. Apart from this, the remainder of the question was often done well.

Standard level part 2: Melting ice.

The main problem when answering this question was in explaining the constant temperature during a phase change. The breaking of molecular bonds was often introduced but it was rare to see a discussion in terms of constant kinetic energy and increasing potential energy of the molecules.

The calculations were done well by those candidates who appreciated the difference between power and energy!

Higher level question 4

Part 1: Melting ice.

The main problem when answering this question was in explaining the constant temperature during a phase change. The breaking of molecular bonds was often introduced but it was rare to see a discussion in terms of constant kinetic energy and increasing potential energy of the molecules.

The calculations were done well by those candidates who appreciated the difference between power and energy!

There were many confused accounts as to why the change in entropy associated with the freezing of ice is consistent with the 2nd law, even by those candidates who correctly stated the law in terms of entropy change.

Part 2: The atom

Generally, knowledge of alpha particle scattering was good. However, many candidates had difficulty with the idea of atomic energy levels and their relation to line spectra. Either they failed to mention the emission of a photon in a transition and/or omitted the relation E = hf in their accounts.

Recommendations and guidance that teachers should provide for future candidates

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, then relevant questions (or parts of questions) from past examination papers 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
- not write in pencil.

Paper 3

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-14	15-19	20-25	26-32	33-38	39-60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-9	10-12	13-16	17-21	22-25	26-40

The areas of the programmed that proved difficult for the candidates

As is usually the case, there were some wide differences in performance between Options by individual candidates. There were many instances where it appeared as if only one Option had been studied in any detail.

Although Option H was popular, average marks tended to be below average. Difficulties are frequently associated with poor ray diagrams.

Options F and G do rely on a good understanding of the basic concepts. Many candidates appeared to have a very superficial knowledge and were, consequently, handicapped when attempting questions that required application.

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

SL only: Option A was very popular. In particular, question A2 (dynamics) was answered well.

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

Standard Level Only

Option A: Mechanics

This was, by far, the most popular Option.

Question 1

Approximately two thirds of the candidates scored well in this question, being able to give satisfactory explanations for their conclusions. However, some thought that, in (a), the centripetal force is equal and opposite to the gravitational force. Others considered constant speed to imply no acceleration.

Question 2

(a) In (i), there were many correct answers. The most common error was a misinterpretation of the graph. In part (ii), there were many answers that were not based on a simple substitution into a relevant equation of motion.

(b) A number of candidates used $g = 10\ ms^{-2}$, despite having calculated an alternative value in (a). In general, there were few problems encountered in this part of the question.

(c) Sketches showed that there were some candidates who had a good appreciation of the effects of air resistance. However, there were many unrealistic attempts. A common error was to show that the horizontal velocity would be greater than the situation where there was no air resistance.

Question 3

(a) Most candidates had some idea of what was required. However, it was common to find that there was no reference to escape from the planet's surface or that the escape speed is the minimum speed. In (ii), a frequent error was to use the diameter, rather than the radius.

(b) Statements of the law frequently lacked a full explanation of the symbols. For example, R was said to be a radius but it was not clear as to whether reference was being made to the body or to its orbit. In part (ii), many answers for the ratio of $\frac{T^2}{R^3}$ were given to two significant figures only. Having determined two ratios, answers often did not include a conclusion.

Option B: Atomic and nuclear physics extension

Question 1

(a) Answers were very varied, revealing a lack of clear knowledge. In particular, there was` difficulty in appreciating the consequence of a constant applied voltage. This may have resulted from a failure to consider carefully any change in the energy and in the rate of arrival of photons. In (i), increased intensity was thought to give an increased current, despite no increase in the maximum kinetic energy of the photoelectrons. In (ii), constant intensity was thought to give constant current.

(b) It should be remembered that, when stating the energy equation for the photoelectric effect, the kinetic energy is the maximum kinetic energy of the photoelectron. In part (ii), there were many clear concise calculations.

Question 2

(a) Not well understood. Those who did associate amplitude with probability frequently forgot the 'square'.

(b) Surprisingly, many candidates could not answer this section correctly.

Question 3

(a) It was expected that this section would be widely known. In fact, there were very few satisfactory statements. Most candidates did not appear to have any understanding of this aspect of the work.

(b) The answer here seemed to be based on guesswork.

(c) Again, there were very few correct responses. It appeared as if candidates were unaware of the fact that the decay constant is defined as the probability of decay per unit time of a nucleus.

(d) There were some good answers here. However, numerous candidates realised that the time would be between three and four half-lives and then assumed a linear relationship. This approach should be discouraged.

Option C: Energy extension

Question 1

(a) There was a certain degree of guesswork involved, as indicated by the suggested reasons. Fallacious reasoning leads to no credit being given.

(b) Well answered.

(c) There were very few correct responses. It appeared as if candidates were familiar with calculating work done where the area is a simple shape such as a rectangle. However, the concept of ‘counting squares’ proved to be too difficult.

(d) Responses frequently lacked full statements. Having established that ☛Q is zero, they then said that the work done is seen as a rise in temperature. Rather, it should be stated that the work done leads to an increase in internal energy. Then, the relation between change in internal energy and rise in temperature should be stated.

Question 2

(a) In general, this section was answered well.

(b) There were some good responses, but candidates should be aware that vague global statements are not awarded any credit. For example ‘there is a danger of an accident’ could apply to any power station.

Question 3

(a) Most candidates could distinguish between the two. However, some did not read the question and did not refer to energy transformations.

(b) There were some very good answers and the question discriminated well between weaker and stronger candidates. The weakest candidates did not appear to understand the nature of the graph.

Higher and standard level

Option D: Biomedical physics

Question 1

(a) As is usual in questions on scaling, some candidates gave clear concise answers whilst others appeared not to understand basic concepts.

(b) Very few answers emphasised that the rate of production of thermal energy in the larger person would be greater leading to the conclusion that the of loss per unit area must be greater. Many candidates falsely based their arguments on the same rate of production of thermal energy.

Question 2

(a) Again, in this question, there were some good answers but also some very poor attempts. The impression gained was that some candidates were poorly prepared to answer questions on this topic.

Question 3

(a) Some answers did not make it clear that soft tissues differ very little in their absorption of X-rays and that the 'barium meal' is a much better absorber, thus providing contrast on the X-ray plate.

(b) Well answered.

(c) The use of a non-uniform field is essential to the successful operation of NMR in that it allows for the localisation of the region being examined. It appeared as if many candidates thought that there is only a large uniform magnetic field.

Higher level only question 4

(a) Most candidates gave the correct response in (i). However, in (ii), answers were disappointing. Although it was realised by most that ionisation is involved, they were not clear that it is the density of ionisation per unit length of track (or per unit volume) that is of importance.

(b) Most candidates referred to either density of ionisation or to a possible repair mechanism. Few referred to both.

(c) There were some good answers that were explained clearly. Some weaker candidates were unable to link the two half-lives.

Option E: The history and development of physics

Question 1

(a) Approximately 50% of candidates gave a correct response.

(b) Very few candidates realised that the arcs resulted from a rotation of the Earth on its axis.

(c) There were some good answers. Some measured the swept angle, whilst others used the arc and the radius. Very few attempted to obtain an average angle. Disappointingly, many weaker candidates did not appear to understand the concept being tested. The question was a good discriminator between candidates of different abilities.

Question 2

(a) With few exceptions, candidates had some basic understanding of caloric. However, that understanding did not extend to the 'self repellent' nature of caloric or to the different absorption abilities of various materials. Consequently, many answers in (ii) and (iii) were trivial.

(b) Generally, candidates were satisfied with making a brief statement, despite the allocation of three marks. It should be realised that the basic information, together with an argument based on that information, is required for full credit. A brief statement would have been indicated by one mark and the action verb would have been different.

Question 3

(a) This section proved to be a good discriminator in that weaker candidates appeared not to understand what was involved. The model assumes electrons orbit at very high speeds, thus giving the impression of a solid atom. A common answer was that the atoms are 'self-repellent'.

(b) In (i), very few realised that it is the charged nature of particles that enables easier detection. Some candidates confused the discovery of the neutron with alpha-particle scattering. Many failed to explain that the emitted 'rays' caused protons to be ejected from hydrocarbons.

Higher level only question 4

(a) Most candidates scored two of the three marks, having omitted any mention of quantisation.

(b) Parts (i) and (ii) were usually completed with little difficulty. However, part (iii) caused problems, with many failing to realise that kinetic energy is given by the expression $\frac{p^2}{2m}$.

(c) In many scripts, this section was not attempted. Very few answers included an acceptable statement of the Uncertainty Principle.

Option F: Astrophysics

Question 1

(a) Most candidates could give at least one relevant fact.

(b) Four marks were available but few candidates made the necessary number of points to gain full credit. In many scripts, a constellation was merely said to be a group of stars.

Question 2

(a) There were many good complete answers. Some candidates lost marks because they merely made reference to 'open', 'flat' and 'closed', without explaining what these terms imply.

(b) There were many very satisfactory answers for these calculations. Where ridiculous answers were obtained, these were accepted without comment by the candidates.

Question 3

(a) Most candidates scored at least two marks in this section. However, many did fail to give sufficient detail. For example, instead of stating 'brightness changes', they should have commented that there is rapid brightening and gradual dimming. Furthermore, it should have been stated that the star is brighter as it expands.

(b) Most definitions were quite adequate. However, there was a minority that not only failed to recall the definitions but also had little idea of the concept. In (ii), there were some clearly explained correct calculations. The most common error was in the manipulation of the equation after substitution of a value for M. A small number did not understand the symbol 'lg' as being the internationally recognised symbol for 'logarithm to the base 10'. In general, these candidates were not disadvantaged in that they were either unable to obtain a correct value of M or substituted incorrectly into the given equation.

Higher level only question 4

(a) Although this should have been recall, there were few correct responses. Indeed, the regions marked frequently indicated that the candidates had little appreciation of the situation.

(b) Very few candidates appreciated that light takes time to travel from the galaxy to Earth. Most attempted to attribute some special property to carbon to make it hotter than its environment.

Higher level only question 5

(a) With few exceptions, part (i) was completed successfully. In (ii), the Sun was frequently marked on the Main Sequence at too high a temperature. In (iii), the start and end points were usually correct but the path between the two was very varied.

(b) Many answers included a description of stellar evolution. Most realised that the star would be expanding but few pointed out that there would be more power but over a much larger area.

Option G: Special and general relativity

Question 1

(a) In most scripts, a satisfactory definition was given.

(b) The most common error was a failure to include a factor of 2.

(c) The performance of candidates in this derivation was disappointing. Although this is a 'standard' proof, many did not appreciate what was expected, despite the structuring provided on the question paper.

Question 2

Generally well done, although explanation was frequently less than adequate.

Question 3

(a) Although most realised that the rest mass involved something at rest, opinion was divided as to whether it is the frame of reference that is at rest or the object within the frame.

(b) Most commented either on the speed approaching the speed of light or on the effect on mass. Few linked these two aspects.

(c) There were many correct answers that were adequately explained. However, a significant minority calculated the total relativistic mass, rather than the mass increase.

Higher level only question 4

(a) In part (i), many were unable to give adequate descriptions. This is one situation where a thorough knowledge of basic aspects would be advantageous. In (ii), some defined a surface, rather than a radius. Part (iii) presented far fewer problems. Most recognised the significance of the difference in distances, but few made a sensible statement. Many just thought that the science fiction would be fact.

(b) Most realised that gravitational lensing is involved. Those who drew a diagram generally scored higher marks. Candidates should be encouraged to draw sketch diagrams, wherever appropriate.

Option H: Optics

Question 1

(a) Many stated that light consists of different colours but far fewer realised that a spectrum is a distribution of the constituents, based on colour or frequency.

(b) Diagrams were, in general, acceptable. The most common error was to show dispersion only at the second face of the prism.

Question 2

(a) Very few showed the block in the correct position. Many drew the position such that the refraction at point P was quite impossible.

(b) There were few correct responses. Mostly, an angle of 49° was calculated and this was then assumed to be the critical angle.

(c) Arguments were frequently marred by poor non-scientific language. For example, the term ‘refracted more’ was used rather than ‘a greater value of refractive index’. Candidates should be encouraged to use scientific language.

Question 3

(a) The majority of diagrams were very poor. Many did not even continue the rays that had been drawn on the diagram. Very few showed parallel rays emerging from the eyepiece in the correct direction. There were, however, a number of very good diagrams, indicating where the final image would be observed.

(b) Definitions were poor. Of those who did give a ratio of two angles, many failed to mention that the angles are subtended at the eye. In part (ii), a satisfactory derivation was rarely seen. Many thought that the magnification is $\frac{f_e}{f_o}$, rather than the inverse.

(c) Most referred to the brightness of the image. A minority mentioned resolution.

Higher level only question 4

(a) Many gave a simple response such as ‘interference’. Very few realised the significance as regards the degree of ‘flatness’ of the plates.

(b) A majority made a reference to the phase change but fewer also discussed the zero geometrical path difference.

(c) There were some good answers for this calculation. However, there were many who quite clearly had no appreciation of the situation.

(d) Many did not recognise that this is an example of thin film interference but rather, attempted to apply laws of refraction. Of those who discussed interference, many thought that colours would be present due to constructive interference rather than absent due to destructive interference.

Recommendations and guidance that teachers should provide for future candidates

- An inspection of the weighting of assessment objectives, as printed in the Guide would indicate that there will always be an element of ‘recall’ in the Papers. Not only do candidates lose comparatively easy marks by not having a thorough knowledge of the factual material but also, they handicap themselves as regards suggestions and discussions related to unfamiliar circumstances.
- When preparing an answer, candidates should look at the number of marks allocated and, to a lesser extent, the space provided on the question paper.
- When drawing diagrams, particularly in Optics, they must be of a sufficiently high quality to show the salient features.
- Where an explanation or a deduction is required, then an unsubstantiated statement of the conclusion, or a conclusion based on a fallacious argument, is not given credit.
- When stating a law, symbols need to be explained.

