PHYSICS TZ2 (IBAP & IBAEM)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 28	29 - 40	41 - 50	51 - 60	61 - 70	71 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-25	26-37	38-48	49-59	60-69	70-100

Internal assessment

Component grade boundaries

Higher level

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

Standard level

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

The range and suitability of the work submitted

The moderation proceeded well this year. The majority of schools followed the correct formalities, including appropriately completed 4/PSOW forms, group 4-project evidence, teacher instructions, and the 4/IA cover sheet. The majority of schools also had relevant investigations for the given IA criteria, and most of the teacher's IA marks were consistent and at the appropriate level. Schools had rich and diverse practical programmes with sufficient hours and there was evidence of an increased use of ICT.

There were a few areas where difficulties occurred.

- Inappropriate investigations for assessment often included the **group 4 project** that involves collaborative work and was occasionally assessed as if it were done by individuals. In general, the first five IA criteria should not be applied to the group 4 project.

- Other examples of inappropriate investigations involve planning exercises where the teacher gave a clearly defined research question. It must be emphasized that **planning (a)** requires an open-ended teacher prompt. Teachers may provide the dependent variable but there must be a number of possible independent variables. The best planning tasks concern the relationship or function between variables, not specific values of physical quantities or the confirmation of known laws.
- Another problem with **planning (a)** work is the increased use of the Internet for research ideas. Teachers should discourage this, as this often leads to a form of plagiarism.
- The **planning (b)** criterion was occasionally inappropriately assessed when students used standard class sets of equipment. For instance, determining the specific heat capacity of an unknown metal.
- Examples of inappropriate assessment under **data collection** as well as **data processing and presenting** included experiments where the teacher told the student what data to record and how to record it, as well as what graph to draw. This was done inadvertently by giving the student an equation or, occasionally, worksheets were given. “Fill in the blank” instruction sheets are inappropriate for assessment.

Candidate performance against each criterion

Planning investigations were occasionally over-marked by teachers because too much information was provided and the student’s marks had to be reduced. Data collection was occasionally over-marked because students and teachers omitted an appreciation of errors and uncertainties. In physics, all measurements involve a degree of uncertainty. Under data processing and presentation, higher-level students often forget that minimum and maximum gradients are expected on linear graphs. Under conclusion and evaluation, students need a clear appreciation of each item of the three aspects. CE is probably the hardest criterion to earn all completes but where moderators increased the student’s mark it was because the teacher seemed to think that a complete means perfect. Each aspect needs to be appropriately addressed for a complete, but mistakes can be made and complete does not mean perfect.

The following contains specific details about the moderation of schools IA work.

A. Where moderators reduce marks.

Planning (a):

- The research question, hypothesis and/or independent and controlled variables are given by the teacher. The relevant aspect should be awarded ‘n’. A general aim is acceptable if the students have significantly modified the teacher prompt or question (e.g. made it more precise).

- The moderator will reduce the second aspect to ‘p’ when the hypothesis has not been explained or the explanation clearly contradicts theory that an average IB physics student can reasonably be expected to know.

Planning (b):

- A method sheet is given which the student follows without any modification *or* **all** students are using an identical method. Appropriate marking is n, n, n = 0.
- It is clear that the students have been told what apparatus and materials they require. The maximum that can be awarded is n, c, c = 2.

Data Collection:

- Students are given a photocopied table with headings and units. The maximum mark is p, n = 0. If the student has not recorded uncertainties in any quantitative data then the maximum that can be awarded for the first aspect is ‘p’.
- The student has been *repeatedly inconsistent* in the use of significant digits when recording data then ‘p’ is the maximum that can be awarded for the second aspect.
- In physics data are always quantitative e.g. drawing the field lines around a magnet does not constitute DC.

Data Processing & Presentation:

- A graph with axes already labelled is provided or students have been told which variables to plot or students follow structured questions in order to carry out data processing. The most the moderator can allow is c, n = 1.
- If there is no evidence of errors being propagated (HL only) or of the total random error being estimated (SL) the maximum moderated mark is c, p = 2. A best-fit line graph is sufficient to meet the requirements for error and uncertainty propagation.

Conclusion & Evaluation:

- If the teacher provides structured questions to prompt students through the discussion, conclusion and evaluation then the maximum award is *partial* for each aspect for which the student has been given guidance. The moderator judges purely on the students input.
- Limited evaluation e.g. the student has only indicated as a criticism that they ran out of time. This is often given c,c,c=3 but is only worth up to a maximum of c, n, p = 1.

B. When moderators do not reduce marks.

In the following cases the moderator will support the teacher’s stance, as they are aware of their own expectations of students.

Planning(a):

- The dependent variable has been given by the teacher or the student has made no mention of a dependent variable

- If the moderator disagrees with the explained hypothesis but feels that it is a reasonable application of IB level knowledge.
- Wrong physics is not penalized.
- The hypothesis explanation is simplistic but the only one possible within the framework of the task. In this case the moderator will support the student but will provide feedback to the teacher as to the poor suitability of the task.
- The independent and controlled variables have been clearly identified in the procedure but are not given as a separate list.
- There is a list of variables and it is clearly apparent from the procedure which are independent and which are controlled.

Planning (b):

- Similar but not identical procedures are given for a narrow task. The moderator will make a comment on the poor suitability of the task on 4/IAF form.
- Moderators do not only mark the equipment list but give credit for equipment clearly identified in a stepwise procedure.
- Moderators do not insist on +/- precision of apparatus to be given in the apparatus list. The concept of recording uncertainties is dealt with in DC.
- Routine items such as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time but others consider them integral part of all lab work and assume their use. Moderators support the teacher's stance here.

Data Collection:

- The student has been inconsistent with significant digits for just one data point or missed units out of one column heading in a comprehensive data collection exercise possibly with several tables of data. If the moderator feels the student has demonstrated that they were paying attention to these points and made one careless slip then the moderator can still support maximum marks under the 'complete not meaning perfection' rule. This is an important principle since often good students responding in full to an extended task unfairly get penalized more often than students addressing a simplistic exercise.
- The student has not included any qualitative observation(s) and the moderator cannot think of any that would have been obviously relevant.
- There is no table title when it is obvious what the data in the table refers to. Except for extended investigations it is normally self-evident what the table refers to and the section heading 'Raw Data' is sufficient. Once again 'c' does not mean perfect.

Data Processing & Presentation:

- The expectation for the treatment of errors and uncertainties in physics is described in the Course Guide and in TSM 1.
- Standard level candidates are not expected to process uncertainties in calculations. However, they can make statements about the minimum uncertainty, based on the

least significant digit in a measurement, and can also make statements about the manufacturer's claim of accuracy. They can estimate uncertainties in compound measurements (± half the range), and they can make educated guesses about uncertainties in the method of measurement. If uncertainties are small enough to be ignored, the candidate should note this fact.

- Higher level candidates should be able to express uncertainties as fractions, and as percentages. They should also be able to propagate uncertainties through a calculation. Minimum and maximum gradients should be drawn on graphs using uncertainty bars (using the first and last data points) for only one variable.
- For both DC and DPP, if the student has clearly attempted to consider or propagate uncertainties (according to whether HL or SL) then moderators support the teacher's award even if they may feel that the student could have made a more sophisticated effort.

Conclusion & Evaluation:

- The student has identified the most sensible sources of systematic error. The moderator will support a teacher's award even if the moderator can identify one more.
- Moderators are more critical in the third aspect that the modifications are actually relating to the cited sources of error. If the moderator feels a task was too simple to truly meet the spirit of the criteria, then comments on the 4/IAF as to the unsuitability of the task giving full justifications will be provided in feedback but the moderator will not necessarily downgrade the student. A consequence is that students could get high DC or DPP marks for some quite brief work on limited data but, if they have fulfilled the aspect's requirements within this small range, then the moderator will support the teacher's marks.

C. Moderation and ICT

The IB encourages the use of data logging even in assessed work. The key axiom to be followed is that the students are to be assessed on their individual contribution to the assessed task. To judge this moderators have to be guided by the teacher who knows exactly what the students had to do. The moderator applies the normal standards regarding expectations of data presentation (units, uncertainties, etc.) and graphs (best fit lines, axes labels, suitable scales, etc.).

Recommendations for the teaching of future candidates

- Students and teachers need to study the IA criteria carefully when doing practical work that will be assessed. Remember that assessed work is only a sub-set of the entire IA work that students should experience.
- Group 4 projects are not appropriate for IA by the first five criteria.
- ICT is encouraged in both assessed and non-assessed practical work.
- Research on the Internet for Planning (a) should not be encouraged. Students should do their own thinking on the given teacher prompt.

- A few schools sent in group 4 project evidence on CDs. In two cases, the CD would not open. Teachers need to make sure that CD evidence is easily readable.
- The international system (SI) of units should be used when possible. One school measured force in dynes and another school measured distance in inches. Students are not penalized for this.
- Graph paper or computer-generated graphs are expected. There is still evidence of hand drawn axes and roughly plotted data points from a few schools.
- Teachers are encouraged to read and study this report.

Further comments

The majority of teachers have a clear understanding of the IA requirements and provide their students with a rich and diverse practical program. Although some schools were moderated down and others up, there was good evidence of a consistent application of the IA criteria. Teachers are reminded that May and November 2008 will be the last examination sessions under the current IA regulations. Teachers need to familiarize themselves with the new IA criteria and requirements for the first examination session of May 2009.

General comments on the written papers

IB multiple choice physics papers are designed to have, in the main, questions testing knowledge of facts, concepts and terminology and the application of the aforementioned. These Assessment objectives are specified in the Guide. It should be noted that multiple-choice items enable definitions and laws to be tested without full recall, but requiring understanding of the underlying concepts.

Although the questions may involve simple calculations, calculations can be assessed more appropriately in questions on Papers 2 and 3. Calculators are therefore neither needed nor allowed for Paper 1.

In Papers 2 and 3, candidates are sometimes asked to write short paragraphs so that their understanding of topics may be assessed. It is clear that, from many answers, candidates have been trained to give definitions and to perform calculations, but have little understanding of the underlying physics. It is this lack of understanding that prevents candidates from achieving the higher grades.

Candidates should be encouraged to give precise definitions for physical quantities. Definitions given partly or totally in terms of units are not acceptable.

Paper one

Component grade boundaries

Higher level

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

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-11	12-16	17-18	19 - 21	22 - 23	24 - 29

General comments

A proportion of questions are common to the SL and HL papers, with the additional questions in HL providing further syllabus coverage.

Only a small percentage of the total number of teachers or the total number of Centres taking the examination returned G2's. For example, at SL there were 79 responses from 380 Centres. Consequently, general opinions are difficult to assess since those sending G2's may be only those who feel strongly in some way about the Papers. The replies indicated that the May 2007 papers were generally well received. The majority of the teachers who commented on the Papers felt that they contained questions of an appropriate level. However, a significant minority thought that both Papers were more demanding. Such changes in demand can be accommodated when grade boundaries are set. With few exceptions, teachers thought that the Papers gave satisfactory or good coverage of the syllabus. When commenting on coverage, it should be borne in mind that this must be judged in conjunction with Paper 2. Most teachers felt that the presentation of the Papers was either satisfactory or good.

Statistical analysis

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

The numbers in the columns A-D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank. The question key (correct option) is indicated by an asterisk (*). The *difficulty index* (perhaps better called facility index) is the percentage of candidates that gave the correct response (the key). A high index thus indicates an easy question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

HL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	123	2745*	270	51	1	86.05	0.13
2	1797*	551	445	367	30	56.33	0.53
3	91	2242*	254	588	15	70.28	0.48
4	295	263	1765*	859	8	55.33	0.48
5	1933*	354	258	637	8	60.60	0.46
6	304	147	157	2577*	5	80.78	0.33
7	464	2570*	115	37	4	80.56	0.13
8	1225*	620	857	483	5	38.40	0.15
9	638*	120	2321	110	1	20	-0.03
10	84	2349*	265	489	3	73.64	0.42
11	1492*	666	265	757	10	46.77	0.35
12	171	38	2717*	264		85.17	0.24
13	179	353	1030	1611*	17	50.50	0.51
14	1744*	152	85	1205	4	54.67	0.34
15	1224	1492*	292	159	23	46.77	0.53
16	156	2209*	323	493	9	69.25	0.48
17	51	501	2544*	90	4	79.75	0.27
18	860	726	326	1256*	22	39.37	0.41
19	2227*	272	383	296	12	89.81	0.44
20	260	90	1844	995*	1	31.19	0.10
21	261	1697	71	1154*	7	36.18	0.09
22	175	2788*	51	174	2	87.40	0.20
23	509	386	2149*	138	8	67.37	0.46
24	105	245	2661*	175	4	83.42	0.26
25	1314	1468*	203	191	14	46.02	0.34
26	369	431	1063	1317*	10	41.29	0.19
27	352	843	1672*	298	25	52.41	0.59
28	2375*	767	20	24	4	74.45	0.17
29	874	195	427	1683	11	0	0.00
30	143	2112*	111	821	3	66.21	0.33
31	713	328	483	1648*	18	51.66	0.39
32	280	279*	205	2415	11	8.75	0.04
33	423	168	2136*	453	10	66.96	0.42
34	2529*	363	180	107	11	79.28	0.38
35	396	694	1712*	360	28	53.67	0.49
36	223	966	1454*	508	39	45.58	0.28
37	1132	1432	185	422*	19	13.23	0.19
38	227	2257*	463	224	19	70.75	0.45
39	204	328	1866*	744	48	58.50	0.32
40	2060*	637	231	241	21	64.58	0.39

Number of candidates: 3190

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	503	578	1232*	425	17	44.72	0.40
2	118	2108*	464	63	2	76.52	0.19
3	1066	329	477	861*	22	31.25	0.23
4	1233*	618	390	497	17	44.75	0.56
5	457	360	1190*	737	11	43.19	0.51
6	69	68	157	2458*	3	89.22	0.21
7	404	220	164	1962*	5	71.22	0.38
8	436	2084*	178	52	5	75.64	0.21
9	1089*	428	651	578	9	39.53	0.24
10	618*	256	1748	129	4	22.43	0.01
11	457	93	1958*	244	3	71.07	0.31
12	2273*	352	82	46	2	82.50	0.35
13	916*	594	361	872	12	33.25	0.30
14	844	728	396	766*	21	27.80	0.36
15	1578*	264	599	299	15	57.28	0.52
16	403	2112*	123	87	30	76.66	0.16
17	325	2172*	83	173	2	78.84	0.39
18	151	587	288	1709*	20	62.03	0.43
19	1332	1013*	272	133	5	36.77	0.38
20	326	1930*	145	335	19	70.05	0.40
21	544	358	1696*	139	18	61.56	0.45
22	452	518	781	973*	31	35.32	0.18
23	206	2081*	152	302	14	75.54	0.34
24	1837*	68	68	766	16	66.68	0.27
25	401	1009	952*	335	58	34.56	0.43
26	418	200	1259	852*	26	30.93	0.42
27	568	366	513	1258	50	0	0.00
28	1531*	345	483	362	34	55.57	0.64
29	633	227	1431*	405	59	51.94	0.51
30	428	213	1826*	214	74	66.28	0.39

Number of candidates: 2755

Comments on the analysis

Difficulty. The difficulty index varies from about 9% in HL and 22% in SL (relatively 'difficult' questions) to about 87% in HL and 89% in SL (relatively 'easy' questions). The majority of items were in the range 30% to 70%. Thus, the Papers provided ample opportunity for all candidates to gain some credit and, at the same time, gave an adequate spread of marks.

Discrimination. All questions, with one exception, 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 or a question with a high difficulty index.

'Blank' response. In both Papers, the number of blank responses tends to increase towards the end of the test. This may indicate that candidates did not have sufficient time to complete their responses, despite a lack of comments from teachers to this effect. Even so, 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. In general, some of the ‘distractors’ should be capable of elimination, thus reducing the element of guesswork.

Comments on selected questions

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

SL and HL common questions

SL Q5 and HL Q4

Candidates should appreciate that the equation applies to situations where the acceleration has constant magnitude and direction.

SL Q10 and HL Q9

There is a popular misconception that a decrease in gravitational potential energy will always be associated with an increase in kinetic energy. If the pipe is full of water and, as shown in the diagram, its diameter is constant, then the speed of the water entering the pipe must be the same as the speed on leaving the pipe. This does, of course, lead to an interesting opportunity for discussion related to conservation of energy.

SL Q14 and HL Q18

Surprisingly, the difficulty index for this item was low. The key was, in fact, simply the expression by which any temperature scale is defined.

SL Q22 and HL Q26

This item is not based on parallel plate capacitors. What is required of candidates is an understanding of the concept of charge conservation and induced charge.

SL Q27 and HL Q29

This item was withdrawn from the test. It was unfortunate that, during the translation of the Paper into Spanish, an ambiguity was introduced.

HL Questions

Q5

The vector representing the force Q in option A should have been vertical. This was not quite so. However, the error does not appear to have disadvantaged candidates. The only possible key is A.

Q17

There was some comment from three teachers regarding the clarity of the diagram. However, the difficulty index was high.

Q20

Candidates did not appear to appreciate that the slopes of the isothermals would not be the same at the higher and at the lower temperatures.

Q32

The Guide does not specify a sinusoidal wave when dealing with the root-mean-square value. Since the magnitude of the current is always I_0, then the r.m.s. value will also be I_0.

Q36

The Guide specifies the experimental 'set-up'. This would include some means by which thermal energy would be dissipated. In this item, the stem refers to cooling and the only option making reference to thermal energy is the key!

SL questions

Q3

This item had a very low difficulty index. The reason for this can be attributed to popular misconceptions of Ohm's law and its application to circuits.

Q24

Candidates need to appreciate what is meant by resistance. It is clear that many have been lead to believe that resistance is calculated in terms of the slope of a *V-I* graph.

Q30

It should be appreciated that nuclear binding energy is concerned with the nucleus and not the energy levels of electrons 'orbiting' the nucleus. The areas of the programme and examination that appeared difficult for the candidates

Recommendations and guidance for the teaching of future candidates

Candidates should make an attempt at every item. Where they cannot provide the correct response, then they should always choose that option which, to them, appears to be most likely. It should be emphasised that an incorrect response does not give rise to a mark deduction.

The stem should be read carefully. It appears that some candidates do not read the whole stem but rather, having ascertained the general meaning, they move on to the options. Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important.

Having decided on the correct response, candidates should check that all other options are not feasible.

Paper two

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 11	12 - 23	24 - 34	35 - 44	45 - 54	55 - 64	65 - 95

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 14	15 - 20	21 - 26	27 - 32	33 - 50

The G2 comments that were received were very helpful when reviewing the perceived difficulties of this year's Paper. The small number of forms received for both Papers means that one should be cautious about drawing any firm conclusions. However at both levels the majority of teachers thought the paper to be of a similar standard to those in previous years. About 40% of Centres thought that the papers were slightly more difficult than last year's. However, the statistics do not bear this out, with the mean mark for each year at both SL and HL being the same. The vast majority felt that the syllabus coverage, clarity of wording and presentation of both papers were either satisfactory or good.

General comments

Many candidates found it hard to perform well on these Papers even though it was felt that there were plenty of marks accessible to those who may struggle with the more conceptual aspects of the course. As identified last year, candidates often lost marks as a result of definitions that lack precision or were expressed in non-scientific language. In fact, precision was an issue throughout the Papers. For example, as for last year, a significant number of candidates lost some relatively easy marks as a result of unacceptable lines of best fit in the data analysis questions (A1). It should be emphasised to students that "line of best fit" does not necessarily mean a straight line. There are many other types of line.

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

The examining team identified the following areas: -

- The difference between proportionality and direct proportion
- Drawing of best-fit lines

- Definition of e.m.f. and Ohm's law
- Circuit calculations
- Free body diagrams
- Determining the resultant of forces
- Difference between stationary and progressive waves
- The principle of superposition
- Resonance
- Electromagnetic induction (HL)
- Drift velocity
- Definition of gravitational field strength (HL)
- Efficiency calculations for heat engines (HL)
- Measurement of half-life (HL)

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

As last year, it was pleasing to see the following skills demonstrated: -

- Mathematical substitution into a given equation
- Symbol manipulation to prove a given relation or formula
- Computational skills
- Radioactive decay

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

There were many common questions between SL and HL. The comments below are arranged in the order that the questions appeared in HL.

Section A

A1 [HL and SL] - Data analysis question

General comment

Many of the G2's suggested that this question would be difficult for students due to its unusual nature. This was far from the case, with candidates often scoring high marks and with even weaker candidates gaining some credit.

It should be remembered that the data analysis question often deals with situations that might be unfamiliar to students.

(a) This was generally well done with many candidates recognising that the lines must be straight. The significance of the origin condition was not always mentioned.

(b) This was not well done. “The instruments have a fault” was a common answer. Few candidates recognised the inherent difficulty of locating the zero position as a result of the container in which the petrol is stored.

(c) [HL only] The better candidates had little difficulty with describing and using this standard procedure.

(c) SL; (d) HL

(i) This was often answered well.

(ii) This was often poor. Many candidates drew a straight line that then curved through the origin.

(iii) Error-carried-forward marks were often gained here even if a straight line had been drawn in (ii), with candidates recognising that their line did not go through the origin or through all the error bars.

(d) SL; (e) HL Most candidates were able to re-arrange the equation to carry out the calculation. Few candidates selected a suitably large value of the radius to obtain a valid value for the energy.

A2 [HL and SL] Electric circuits

(a) Few candidates were able to define e.m.f or state Ohm’s law correctly. For e.m.f, definitions often mixed units and quantities e.g “energy per coulomb”. It should also be emphasised to students that Ohm’s law does not state that the potential difference is proportional to current.

(ii) **[SL only**] Many candidates incorrectly thought that the resistance is the slope of the graph.

(b) (i) –(iii) Many candidates gained full credit here.

(c) This was not often done well. A common mistake was to make a comparison between the resistance of the load in the first circuit and the total resistance of the second circuit. Another mistake was to ignore the internal resistance in the second circuit.

A3 [HL only] X-rays

(a) Many candidates were able to draw an acceptable X-ray spectrum but it was also evident that some candidates were totally unfamiliar with the spectrum.

(b) (i) This was often done well but weaker candidates frequently attempted to use the de Broglie equation.

(ii) Many candidates calculated the correct value but failed to explain their calculation.

Section B

B1[HL and SL] Model helicopter

(a) Many candidates were familiar with, and able to state, a version of Newton’s third law although not very many were able to proceed beyond this in order to show how it leads to the principle of momentum conservation.

(b) Many candidates realised that the air supports the helicopter but not all made any connection with Newton's third law and equilibrium.

(c) Nearly all candidates gained the mark here.

(d) and (ii) Calculating the mass of air and rate of change of momentum defeated most candidates.

(e) The link between this and the answer to (d) (ii) was often made and many candidates gained an error-carried-forward mark here.

(f) Again, error-carried-forward marks were often gained here.

(g) Free-body diagrams were often poor, with a variety of fictitious forces shown such as the forward thrust force.

(h) Explanations as to why a forward force acts on the helicopter were often inventive but not often correct. A large amount of incorrect and inappropriate work was seen with many candidates mixing force and acceleration diagrams. Correct resolution, or a correct triangle with correct explanation, was rarely seen.

(i) **[SL only]** Most candidates realised that the helicopter would experience resistance to motion but few were able to explain that this force increased as the speed of the helicopter increased.

(i)-(j) **[HL only]**

(i) This was usually answered correctly.

(j) (i) This was usually answered correctly.

(ii) Strictly speaking, it should have been stated in the question that CD and AB are adiabatic changes. However, the vast majority of candidates understood that something must be happening during BC and DA. Others clearly had no understanding of the situation. In this respect, the examining team did not feel that any candidates had been disadvantaged by the omission.

B2

B2 Part 1 [HL and SL] Waves

(a) A second condition often eluded candidates.

(b) Many candidates confused amplitude with displacement when describing the principle of superposition.

(c) (i) Although this was often well-answered, there were some very wild guesses.

(ii) A pleasing number of candidates recognised the importance of the stationary positions of the nodes but there were some answers where it was stated that the wave is moving so fast that it appears to be stationary.

(d) (i) The fact that resonance results in an increase in amplitude escaped many candidates even though they then went on to complete the calculation in (ii) correctly.

(ii) This was often answered well.

(e) [HL only]

(i) Many candidates realised that the waves would result in beats, but failed to actually describe what would be heard.

(ii) Many candidates were able to calculate the frequency of the two waves and knew the relation between the frequencies and the beat frequency.

B2 Part 2 [HL only] Neutron Star

(a) A reference to small/point/test mass was often missing.

(b) (i) The relation was often deduced correctly but without explanation.

(ii) The calculation was often correct.

(c) The link between gravitational field strength and centripetal acceleration was often missed with many candidates only partly completing the question.

B2 Part 2 [SL only] Radioactive decay

(a) (i) The proton and neutron were often correctly identified as being nucleons.

(ii) Few candidates wrote complete explanations and, despite the question stating that answers should be in terms of the nucleons and the forces between them, any reference to the strong nuclear force was missing in many answers.

(b) (i) Often well-answered.

(ii) Conversion from the atomic mass unit to joule often proved troublesome.

(c) This was often well-answered but weaker candidates omitted an explanation for their answers.

B3

B3 Part 1 [HL and SL] Gases and liquids

(a) Many candidates answered this well but several gave only one difference expressed in two different ways. The word “average” was often omitted when mentioning separation.

(b) Many candidates realised that molecules have different kinetic energies but failed to recognise the significance of the action verb “explain”.

(c) Thermal capacity was sometimes confused with specific heat capacity.

(d) (i) Usually well-answered.

(ii) The calculation was often correct.

(iii) The calculation was often correct.

B3 Part 2 [HL only] Electrical conduction and induced currents

(a) Very few candidates understand the concept of drift velocity.

(b) (i) There were very few correct answers in (i) and consequently this led to inappropriate answers in (ii)

(iii) The explanation defeated many candidates.

(c) (i) Although Faraday's law was often quoted correctly, it was rarely applied correctly in order to answer (ii).

(iii) In spite of poor answers to the rest of this question, many candidates had success with one or both of the calculations.

B3 Part 2 [SL only] Electrical conduction and the force on a conductor in a magnetic field

(a) (i) Surprisingly, this was often answered incorrectly.

(ii) Very few candidates understand the concept of drift velocity.

(b) (i) Surprisingly, this was often answered incorrectly.

(ii) The relationship was often derived correctly.

(c) (i) and (ii) Both of these parts were often well-answered.

B4

B4 Part 1 [HL only] Radioactive decay

(a) (i) The proton and neutron were often correctly identified as being nucleons.

(ii) The quark structure of nucleons was well known.

(iii) Few candidates wrote complete explanations and, despite the question stating that answers should be in terms of the nucleons and the forces between them, any reference to the strong nuclear force was often missing.

(b) (i) Often well-answered.

(ii) Many answers omitted reference to conservation of energy and/or the beta spectrum

(iii) Conversion from the atomic mass unit to joule often proved troublesome.

(c) (i) and (ii) The technique for measuring the half-life of isotopes with long half-lives was not well understood. Few candidates appreciated that the activity decreases little with sensible time measurements and therefore knowledge of the initial number of atoms in a sample needs to be known

B4 Part 2 [HL only] Friction

(a) Generally well-answered.

(b) Few candidates referred to surfaces in contact and many implied that static friction is always greater than dynamic friction.

(c) Generally well-answered.

(d) Many candidates thought that the block would move with constant speed.

Recommendations and guidance for the teaching of future candidates

Whereas candidates in this year's examination appeared to do well in calculations, a common theme has been the lack of precision in written answers, especially in those requiring an explanation. Arguments that logically follow through relevant stages were few. Candidates should be encouraged to be able to define the terms that they are using. A significant number of candidates (particularly at Standard Level) appeared to be under-prepared for this examination. For these candidates, the experience cannot have been rewarding or encouraging. Candidates should also be alerted to the significance of the action verb that starts a question; an "explain" requires a more detailed answer than a "state".

As has been suggested in the past, the examination team recommends working through past papers (and the associated mark schemes) as a good preparation for the examination. Not only will this give candidates a familiarity with the format of the examination but also many should be able to gain a better understanding of the level of detail required, as well as the skills that are being assessed. Some candidates answered all the questions on separate sheets of paper and wrote nothing on the script itself. This included copying graphs that must have been very time consuming for those candidates. Situations such as this would have been avoided if those candidates had practiced with past papers. Candidates must also be encouraged to write clearly and legibly, to avoid the use of a pencil and always to have a ruler with them during the examination.

Paper three

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 20	21 - 25	26 - 31	32 - 36	37 - 60

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 3	4 - 7	8 - 11	12 - 15	16 - 20	21 - 24	25 - 40

General comments

The majority of candidates appeared to find the Paper accessible with many examples of good understanding of the material. There was no evidence that candidates were short of time to complete their work.

The feedback from teachers on the G2 forms for SL and HL is summarized as follows. However, it should be realised that fewer than 25% of Centres submitted G2 forms.

Standard Level

- 76% found the paper to be of a similar standard to last year, 10% easier and 14% more difficult. Overall, 96% found the paper to be of an appropriate standard and 3% thought it too difficult with 1% finding it too easy.
- about 24% found the syllabus coverage satisfactory, 6% thought it was poor and 70% found it good.
- about 31% found the clarity of wording satisfactory and 68% found it good with 1% finding it satisfactory.
- about 17% found the presentation satisfactory and 83% found it good.
- as in previous years, the most popular options were A (Mechanics) and H (Optics).

Higher Level

- about 77% found the paper to be of a similar standard to last year, 6% a little easier with17% describing it as a little more difficult. Overall, 96% found the level of difficulty appropriate and 2% thought it too easy with 2% thinking it too difficult.
- about 34% found the syllabus coverage satisfactory and 66% good
- about 34% found the clarity of wording satisfactory, 64% found it good and 2% found it poor
- about 18% found the presentation satisfactory, 82% thought it was good
- As in previous years, the most popular options were H (Optics), F (Astrophysics) and G (Relativity).

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

The areas identified by the examination team as being difficult were as follows:

- Definitions and application of ideas of gravitational potential.
- Explaining concepts in Physics in a way that demonstrates understanding (e.g. explaining proper time, Galilean transformations, cosmological background radiation, and diffraction phenomena)
- Comparison of X-ray spectra.
- Relationship between atomic line spectra and the equivalent energy levels.
- The application of the second law of thermodynamics to a real situation.
- The full mechanism of a nuclear chain reaction.
- The basis of computed tomography imaging.
- Phenomena related to the motion of the Moon around the Earth.
- Comparison of the Thomson and Rutherford models of the atom.
- Resolution effects in diffraction.

- Providing sufficient depth and detail in questions with a mark allocation of more than one mark. This was particularly true in those questions involving the action verbs “explain”, “discuss” and “describe”.

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

Simple mathematical calculations were often done well by the majority of candidates. Many candidates appeared well prepared and able to produce some excellent answers that showed a good understanding of the concepts, particularly in the Mechanics, Astrophysics and Optics options.

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

SL only

Option A – Mechanics

A1 Projectile motion

Very many candidates were able to score full marks on this question with well reasoned accounts of the physics. However, there were some errors due to poor treatment of significant figures. The calculation of the maximum height of the wall gave problems to some who were unable to access the second part of the calculation, having successfully identified the correct time to the wall. Some candidates did not appreciate that the time for the horizontal and vertical travel to the wall is identical.

A2 Equilibrium in the context of a crane

Many candidates recognised that the net forces acting on a body in equilibrium equate to zero but then failed to make a similar statement regarding the net torque, often re-stating the force requirement in a different way. For the calculation of the distance in the second part there were very many accurate and well-explained solutions.

A3 Gravitational potential

This question gave more difficulty to candidates, many beginning with an inadequate definition of gravitational potential at a point. Failures here included definitions in terms of either the total energy of the body or the force acting on it. Many failed refer to the potential at infinity. The sketch of gravitational potential also gave problems. Many sketches showed an asymptotic behaviour at both axes (instead of at the distance axis alone). Few candidates showed the line with an intercept on the potential axis – this was often asymptotic too. In general the quality of sketches was poor with the ‘asymptotic’ behaviour very carelessly drawn. Candidates would do well to take much more care over such diagrams.

The impact speed of the meteorite at the Moon was usually well done, but some went back to *ab initio* calculations and made errors. Candidates often neglected to take the square root as the last part of the calculation. The factors that may increase the impact speed were poorly stated. Surprisingly the simple final part, which asked for suggestions for the changes in energy with distance, produced evidence of confusion as to the true nature and direction of the energy changes.

Option B – Quantum Physics and Nuclear Physics

B1 X-ray spectra

Many were able to complete the routine calculation of minimum X-ray wavelength, but then made poor attempts at the modification to the intensity–frequency graph. Despite the strong hint (with an extended *x*-axis) almost all failed to make the link between doubling the accelerating potential difference and the change in the maximum frequency of the X-rays.

B2 Atomic spectra

Explanations of the relationship between atomic line spectra and atomic energy levels were poor and incomplete. The essential connections do not lie well in the minds of the candidates. Almost all scripts contained satisfactory deductions of the photon energy. Only approximately half of the candidates could identify both the energy level transitions and the direction in which the electron transition occurs.

B3 Radioactivity

Most were able to identify the electron anti-neutrino in the carbon-14 decay and were able to state the class of fundamental particle to which the beta particle belongs. Equally successful were the calculations of decay constant and the age of a bowl in a carbon-dating experiment. However, few were able to give a complete and accurate description of the determination of the half-life of a nuclide with a long half-life. Descriptions were facile and usually based on practical work involving a short half-life isotope that the candidate may have seen carried out.

Option C - Energy extension

C1 Thermodynamic Processes

Many candidates were confident in their description of an adiabatic change. However, many became confused with the graph and mis-identified the direction of the changes in the refrigerator. The isobaric change was correctly identified by substantial numbers but the direction of energy flow gave more difficulty with many wrong answers, even allowing for an error carried forward for those who initially gave an incorrect direction of change. Most recognised that the work done during one cycle of the change is equal to the area within the cycle on the graph and could then go on to calculate the work done correctly within acceptable limits.

C2 Nuclear fission

This straightforward, mostly descriptive question was disappointingly answered. Candidates too often reverted to bland and incomplete statements of the physics and failed to think about what examiners might actually want. In the first part, candidates were asked to outline whether nuclear fission constitutes a renewable or a non-renewable source. Most simply stated their view without justification. This was unacceptable. Equally, the vast majority gave very low-level advantages of nuclear fission over fossil fuel burning and typically scored one out of the available two marks. Very few discussions of the nuclear chain reaction mentioned the production of energy which was a clear part of the question. The calculation rarely attracted full marks with confused and ill-presented work. Approximately one-third of candidates carried all parts of the calculation through to a correct solution. The 23% efficiency presented particular difficulties to many.

SL and HL combined

Option D - Biomedical physics

D1 Scaling factors

This question was expected to be answered well but a surprisingly small number of candidates were able to make any real progress with the problem. The combination of a cube and square in the ratio was too demanding for many.

D2 Sound intensity

Although many wrote fully on the subject of the ear, there was little substance in the answers and most failed to address the topic of the question. The middle ear was not described as a device for *increasing* the pressure variations, and the mechanisms at work in the cochlea were not understood. The role of changes in the cochlea in the discrimination of speech was described at a very simplistic level, with a lack of clarity in describing what produces poor speech discrimination.

D3 X-ray absorption

The statement of attenuation mechanisms in X-radiation was well done. However, few were able to give convincing accounts of either computer tomography or how its images differ from those of conventional X-rays.

D4[HL only] Metabolic rate

This question was answered superficially. There were four points to be made but often candidates could only give two or three. Many mentioned or (better) described basal metabolic rate, but there were only weak accounts of the other energy losses involved in the metabolism.

D5[HL only] Radioisotopes in medicine

Whilst the straightforward calculation of effective half-life was universally well done, the remaining descriptive parts of the question indicated that candidates are far less comfortable with the concepts that underpin the ideas of effective, physical and biological half-life. The descriptions were incomplete and weak.

Option E – The history and development of physics

E1 Planetary motion

Descriptions of retrograde motion often failed to include the important information that the apparent motion of the planets is against the background of fixed stars. In the second part, candidates draw an acceptable visual aid on the diagram but then failed to use this in their explanation. There were two questions testing the candidates' understanding of the motion of the Moon relative to the Earth, a topic that has not been examined for some time. Candidates were found wanting here, with very few recognising that the Moon rotates on its axis in the same time that it takes to rotate around the Earth. Equally, few appeared to understand that the Moon travels around the Earth by about $\frac{1}{28}$ th of its orbit in 24 h and therefore rises in a different place each day.

E2 Newton's law of gravitation

Many candidates understood what the universality of the law of gravitation means, but were less confident when it came to explaining the contribution that Newton made to the acceptance of Kepler's laws.

E3 Thomson determination of e/m_e

Candidates were asked to outline how speed was measured in this experiment and many gave almost complete accounts. Some, however, had very little idea of the experiment or its details. Diagrams, where given, were poor and lacked both detail and quality.

E4 Models of the nuclear atom

Although many had reasonable ideas about the Thomson and Rutherford models, often essential points were omitted or were vague. The relative scale of the two models was often not appreciated in answers and it was rare for a candidate to give a complete description of the nucleus in the Rutherford case.

E5 [HL only] Bohr model of the hydrogen atom

The successes and limitations of the Bohr model were well known and clear, but the standard calculation of the Rydberg constant could not be shown by many. There was a failure to appreciate that values of n have to be 1 and ∞ for this calculation and many were defeated by the algebra in this question. This is a standard calculation that should have been accessible to more candidates. Inevitably, the ideas of de Broglie and Schrödinger were confused and many candidates simply failed to answer the question with its emphasis on outlining how stable orbits can exist without contradicting electromagnetic theory.

Option F – Astrophysics

F1 Star brightness

This option opened with a simple definition of luminosity which most gave correctly. Some gave the answers 'energy' or 'power per unit time' and were clearly confused. Equally many were able to quote one factor that determines luminosity. A good number could then go on to score full marks in their outline of why Cepheid variables have a periodic variation in luminosity; they appreciated both the physics of the changes in the variable star and how these lead to changes in luminosity. There were many pleasing and well presented accounts of the calculation of star distance. Candidates explained the ratio work and arrived convincingly at an accurate answer. Failures usually featured candidates who tried to work from data from star B only.

F2 Cosmology

Most gained one of the two available marks for the spectrum of the black body. The most common error was a failure to recognise that the curve is not only higher but that the maximum is shifted to lower wavelengths. The remaining parts of this section demanded a clear understanding of cosmological background radiation, how it arises and what can be deduced from its presence. Responses were confused and meandering. This topic was not clear in the candidates' minds. The final part of the question asked for a sketch of the size of the Universe versus time for the open, flat and closed Universe. This was very poor. Almost all candidates showed the curves coincident at the beginning of time rather than at the present time. The shapes of the curves were poor and unconvincing. Students may have only half-remembered the fine detail of these curves. The question testing knowledge of the required density if the Universe is to be closed was well done by most, but some failed to recognise that gravity is the force responsible for the closure.

F3[HL only] Galaxies

Many candidates failed to recognise that a galaxy has a gravitational aspect to its formation. Very few candidates were able to score full marks when describing a galactic supercluster and it was clear that many were meeting the term for the first time. The calculation of the age of the Universe was done well.

F4 [HL only] Stellar evolution

Most had an understanding of the Chandrasekhar limit but some were unable to express it sufficiently clearly to be given credit. It was important to indicate clearly whether the star has to be above or below the limit in order to proceed to the white dwarf stage. On the other hand, very many were able to describe the evolution of large stars to either their neutron or their black hole stage, although some forgot to mention the role of the supernova in this formation.

Option G - Relativity

G1 Time dilation

Many candidates' answers to the question on proper length suggested that they had some understanding of the concept. On the other hand proper time was often poorly expressed and described. The following calculations involving the decay of the muon were well done but with many significant figure errors. The second part was often associated with a correct calculation of γ but a failure to apply this figure correctly. Time dilation was poorly explained in the context of the muon, with most comments simply describing time dilation in general. Candidates had failed to read the question.

G2 Relativistic mass change

The sketches of the variation of electron mass with speed were often so negligent as to lose marks. The essential physics is that a non-zero electron mass rises asymptotically at a value for *v/c* of 1. Candidates showed this increase beginning at values of *v/c* that were too low and the drawings of the asymptote were often wayward. Candidates really must pay more attention to delivering sketches that show essential features clearly. The calculation parts were well done by many.

G3 Simultaneity

In what was evidently a well-rehearsed question, many had a clear idea of the essential physics but were often poor at expressing it. Very few suggested that the lights were observed to switch on simultaneously but by no means all those who knew the correct answer were able to gain full credit for their explanations.

G4[HL only] Space-time and black holes

Candidates have a good sense of what is meant by a black hole in this popular area of the Option and were able to express it well. However, the relationship between the Schwarzchild radius and the mass of a black hole was not well recognised and consequently poorly done. The effect of a black hole on an object approaching it on a non-collision course was well described by many. However, the full ramifications of how gravitational attraction is perceived to arise from space-time warping were not usually clearly described. In particular, although candidates often recognised how the curvature of space-time leads to a curved path because this is the shortest distance in the distorted space-time, they failed to explain how the subsequent motion is judged to be equivalent to a force, which we describe as gravitational.

Option H Optics

H1 Refractive index

The ray diagrams of the relatively easy situation of real and apparent depth were disappointing. Diagrams were crudely done, sometimes without a ruler. Candidates often failed to show any significant change in the direction of the ray as it left the water. It is important to make diagrams clear and unambiguous. Almost all candidates then went on to make a successful attempt to calculate the depth of the swimming pool. Similar criticisms can be made of the diagrams indicating the rays entering the eye of the diver. The angles of incidence and reflection frequently bore no relationship to each other. At this level it is important for the candidate to demonstrate a knowledge of basic facts by drawing acceptable diagrams.

H2 Converging lens

The ray diagrams often showed correct physics, but again the quality of the work left much to be desired. Only a minority could not proceed to construct the final virtual image. The near point definitions were often loose and revealed a lack of complete understanding of the true meaning of this important parameter. About half the candidates were able to arrive at a completely correct object-lens distance in the calculation. Common errors included a failure to appreciate the correct sign in the lens equation or a failure to compute the correct image distance for the situation in the question. Many candidates understood the meaning of spherical and chromatic aberration and ascribed reasons for their occurrence correctly. However, clear descriptions of the appearance of the image with these two aberrations were comparatively rare and often confused. Candidates who understood spherical aberration frequently went on to suggest an appropriate reduction technique.

H3[HL only] Diffraction and resolution in a telescope

Good answers to this question were rare indeed. The diffraction fringe pattern was often poorly labelled and the diameter of the central maximum on the plate was often confused with the radius. However, candidates were rather better at computing the resolution of the telescope and hence the separation of the stars. The descriptions of the changes in the appearance of the image were often vague and difficult to follow. Candidates struggled to express their ideas.

Recommendations and guidance for the teaching of future candidates

Recommendations from the examination team included the following ideas:

- Candidates should be given more opportunities during the course to practice examination style problems.
- Candidates should be provided with, and given assistance with, the list of action verbs as specified in the syllabus. It is clear that many candidates do not recognise the difference between, for example, the stating and the explaining of an answer.
- When using a diagram to help answer a question, candidates should be encouraged to pay attention to the precision of the diagram. This is particularly true of ray diagrams, as many candidates failed to use even a sharp pencil and / or a ruler.
- Enough time should be devoted to cover in depth the Options chosen.