November 2013 subject reports

Physics

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 29	30 - 43	44 - 53	54 - 62	63 - 72	73 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 27	28 - 38	39 - 47	48 - 58	59 - 68	69 - 100

Higher level internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 27	28 - 33	34 - 38	39 - 48

Standard level internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 27	28 - 33	34 - 38	39 - 48

General comments

The IA moderation for the November 2013 exam session proceeded with no significant difficulties. A variety of 4/PSOW forms were used but they all included the required information and were completed correctly. Most teachers annotated the candidate reports explaining the IA assessment levels. This aided moderators. The majority of candidate reports were word-processed and graphs were drawn on graphing programs.

The range and suitability of the work submitted

Most centres had a comprehensive practical program and teachers are assessing appropriate work. There was wide use of ICT. Although mechanics has traditionally been the main focus of practical work, there is a range of hand-on activity in all major physics topic areas. The difficulty of investigations is consistently at the correct level. Indeed, this exam session the quality of IA work was exceptional and some of the candidate reports were simply amazing.

Candidate performance against each criterion

Design - Most centres are using established design prompts. In a few cases, however, the prompts were not appropriate because the teacher gave the candidate a relevant formula and the independent variable. Good design prompts are ones that have candidates looking for a function between two variables, not a specific value. Candidates need to be reminded that for a complete under design that variables need to be defined (and vague statement like “I will measure the time” needs to be clarified as to just how this will be done). Operational definitions help in the design of a method as well. This comes under the ability to control variables. Design is not a research or textbook based activity.

Data Collection and Presentation (DCP) - As in the past, candidates earned the highest marks under the DCP criterion. Moderators are looking for a brief statement to why the candidate gives a particular value of uncertainty, and this holds for both raw and processed data. Presenting data on graph is expected and indeed required for full assessment under DCP. Teachers need to be aware of this requirement.

Conclusion and Evaluation (CE) - Under CE aspect 1, candidates need to think beyond the given data in order to provide a justification based on a reasonable interpretation of the data. Such insight might look at the extremes of the data range, the origin of the graph, the y-intercept, for some physical meaning. Candidates might even give the overall relationship some physical interpretation. Teachers need to look for this when awarding aspect 1 a complete, as many times moderators had to change a ‘complete’ to a ‘partial’. CE is best assessed when candidates also have designed and performed the investigation themselves. Many candidates construct two parallel columns corresponding to CE aspects 2 and 3. This helps the candidate make their ideas clear.

Recommendations for the teaching of future candidates

- Many centres are allowing candidates only two opportunities to earn their best marks. It is recommended that after candidates become familiar with the expectations of IA, that they have a number of opportunities to be assessed, perhaps 3 or 4 from which the highest two of each criterion are used for their IA mark.

- Because the IA mark is part of the candidates overall IB grade, it is important that candidates work on their own. They must collect their own data, decide on how to process it and write the report on their own. Group work is not allowed.

- Although many centres correctly appreciate errors and uncertainties, this remains one of the weaker areas for some other centres. Teachers need to address the appropriate treatment of uncertainties in lab work.
- Teachers should bear in mind that it is often too difficult to come up with improvements for well-established, traditional experiments for assessment of CE.

Further comments

Teachers must assign appropriate tasks when assessing IA. Only a few centres failed to appreciate this and the marks for these centres were adjusted. Teachers are reminded that a design investigation is not meant to be research project, that under design no hypothesis is expected, and that the teacher must not suggest the independent variable to the candidate.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 17	18 - 24	25 - 27	28 - 30	31 - 33	34 - 40

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 16	17 - 18	19 - 20	21 - 22	23 - 30

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.. 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 papers were generally well received, with many of the G2's received containing favourable comments. The majority of the teachers who commented on the Papers felt that they contained questions of an appropriate level and generally in line with last year's papers.

With few exceptions, teachers thought that the presentation of the Papers was good to excellent. Generally teachers thought that the clarity of the wording good to excellent, but 25% of both HL and SL centres commented that the clarity of wording was fair. Unfortunately there were no detailed comments to indicate how the wording could be 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 a shaded cell.

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	55	395	632	31	2	56.68	0.68
2	331	644	74	64	2	57.76	0.66
3	23	31	182	879		78.83	0.4
4	72	459	346	235	3	31.03	0.48
5	1039	16	26	31	3	93.18	0.13
6	1075	9	7	23	1	96.41	0.09
7	13	24	37	1041		93.36	0.17
8	85	79	148	798	5	71.57	0.53
9	505	23	482	103	2	45.29	0.3
10	96	314	130	570	5	51.12	0.49
11	863	113	12	125	2	77.4	0.26
12	69	70	624	345	7	55.96	0.62
13	80	164	695	174	2	62.33	0.53
14	4	56	1039	16		93.18	0.14
15	413	590	75	35	2	52.91	0.64

16	37	21	1029	27	1	92.29	0.16
17	69	96	904	44	2	81.08	0.35
18	62	118	697	233	5	62.51	0.34
19	5	1001	50	57	2	89.78	0.17
20	221	51	768	63	12	68.88	0.56
21	491	124	19	480	1	43.05	0.61
22	613	67	81	352	2	54.98	0.55
23	722	183	115	92	3	64.75	0.5
24	83	904	55	71	2	81.08	0.37
25	193	581	262	76	3	52.11	0.35
26	27	12	6	1068	2	95.78	0.08
27	56	812	216	30	1	72.83	0.17
28	191	210	50	648	16	58.12	0.46
29	570	329	180	34	2	51.12	0.11
30	75	177	807	52	4	72.38	0.44
31	26	141	421	520	7	46.64	0.41
32	47	81	97	886	4	79.46	0.46
33	403	476	45	187	4	42.69	0.44
34	5	38	9	1059	4	94.98	0.12
35	113	715	156	117	14	64.13	0.45
36	468	114	480	45	8	43.05	0.47
37	700	269	122	23	1	62.78	0.41
38	964	88	36	22	5	86.46	0.3
39	169	766	142	35	3	68.7	0.47
40	37	1027	24	24	3	92.11	0.18

Number of candidates: 1115

SL paper 1 item analysis

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	86	528	433	55	2	39.22	0.59
2	84	750	232	37	1	67.93	0.44
3	399	211	136	356	2	19.11	0.24
4	24	57	272	750	1	67.93	0.49
5	617	397	61	28	1	55.89	0.22
6	151	587	117	248	1	53.17	0.46
7	82	501	217	304		19.66	0.29
8	923	33	56	90	2	83.61	0.31
9	131	192	679	100	2	61.5	0.38
10	976	33	24	71		88.41	0.22

11	23	47	114	917	3	83.06	0.36
12	183	367	162	392		35.51	0.38
13	690	143	57	213	1	62.5	0.42
14	47	846	187	22	2	76.63	0.32
15	193	88	451	368	4	40.85	0.32
16	104	685	189	126		62.05	0.45
17	96	180	776	52		70.29	0.47
18	187	657	201	59		59.51	0.39
19	84	110	606	302	2	54.89	0.22
20	23	925	71	85		83.79	0.27
21	120	106	104	773	1	70.02	0.48
22	397	104	538	58	7	48.73	0.47
23	37	36	19	1012		91.67	0.17
24	406	45	67	586		36.78	0.49
25	121	174	215	592	2	53.62	0.67
26	25	86	23	970		87.86	0.23
27	37	269	794	3	1	71.92	0.39
28	411	59	514	119	1	10.78	0.08
29	60	729	171	142	2	66.03	0.54
30	583	282	190	46	3	52.81	0.43

Number of candidates: 1104

Comments on the analysis

Difficulty

The difficulty index varies from about 31% in HL and 11% in SL (relatively ‘difficult’ questions) to about 96% in HL and 92% in SL (relatively ‘easy’ questions). The papers gave an adequate spread of marks while allowing all candidates to gain credit.

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 or a question with a high difficulty index.

‘Blank’ response

In both Papers, there were a small number of blank responses throughout the paper. This may indicate that some candidates had insufficient time to complete their responses, but it may also indicate that they were more poorly prepared for items occurring throughout in the written syllabus. 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 ‘distracters’ should be capable of elimination, thus reducing the element of guesswork.

The strengths and weaknesses of the candidates in the treatment of individual 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. Feedback will be given only on selected questions, i.e. those that illustrate a particular issue or drew comment on the G2’s.

HL and SL common questions

HL Q1 and SL Q1

A number of candidates opted for B. Candidates appeared to have added the absolute uncertainty rather than adding the relative uncertainty as the approximation for finding the uncertainty in multiplication.

HL Q4 and SL Q7

This question proved to be difficult for candidates with many opting for the distractors B and D. Candidates should know that in calculating work done by a varying force $F_{average}$ needs to be used rather than the initial or final force.

HL Q10 and SL Q12

Many candidates opted for B and this may be down to not taking the time to read the question carefully. Typically, questions on simple harmonic motion ask for the relationship between acceleration and displacement, but in this case, the question asks for the relationship between acceleration and velocity. Candidates will benefit from checking that the other options are wrong before quickly deciding upon their initial thoughts.

HL Q12 and SL Q15

A number of candidates were getting the relationship the wrong way around (Amplitude and intensity).

HL Q20 and SL Q 22

This questions proved to be somewhat difficult, especially for SL candidates. A number of different approaches could be used here, such as looking at the dimensions of the fundamental units, or by considering the cause and effect of increasing each one of the variable.

HL Questions

HL Q9

A large number of candidates opted for C. This stems from the misconception that the entropy of the surroundings must always increase, but there are situations where there may be a decrease in the entropy of the surroundings.

HL Q19

Although the vertical lines in diagrams A and B should have been curving away slightly from the centre, these are schematic diagrams and posed no obvious concern for the candidates. The vast majority of the candidates opted for the correct response.

HL Q21

Although the ball is launched with a velocity of V, the question refers to the vertical component. Therefore, the initial velocity in the vertical direction must be less than this value. Many candidates failed to pick up on this point.

HL Q23

The question can either by approached from taking the gradient of the electric potential graph to provide the electric field strength, or by knowing that the electric field inside a charged sphere is equal to zero, they would be able to opt for the correct response.

HL Q25

The correct response here is B. As the rod falls, an electric current in induced, forcing the electrons across the diameter of the wire. This in turn, produces an upward force on the rod as a whole in line with Lenz's Law.

HL Q28

There was an issue with the Spanish translation of the stem to this question. Statement III "La energia cinetica del electron" should have corresponded to the English "The kinetic energy of the electron increases". This statement made up part of the correct answer (D), which refers to this statement and statement I. A manual adjustment was made to the marks for each candidate to ensure no candidate was disadvantaged for this question.

The paper has been amended for publication to the correct translation of "La energia cinetica del electron aumenta".

HL Q29

A number of candidates opted for B, seemingly forgetting the reciprocal relationship between energy and the wavelength of the photos emitted.

HL Q31

This question provided a fairly even split between response C and D with many candidates not appreciating that the magnetic field also has a role in the ion selection process.

HL Q33

There was a fairly even split between response A and B for this question. This may have been caused by candidates either not reading the responses carefully enough or not appreciating the difference between the two.

HL Q36

It would appear as is many candidates were not converting their responses into a percentage and leaving it as 0.02.

SL only Questions

SL Q3

Although in an examination, candidates still need to appreciate when they may need to take a little more time to fully understand the question and appreciate the labelling on the axis of the graphs. A sizeable number of candidates opted for A despite this being the only graph which begins with an acceleration of 0. The typical velocity-time graph for objects falling in air would be of this shape and this seems to led to confusion for these candidates.

SL Q24

This proved to be a difficult question, with many candidates opting for response D. This is possibly down to the fact that they encountered these units in the topic on binding energy so they have made an incorrect connection. Often such questions can be approached by elimination. By being aware that responses C and D both involved energy, they were unlikely to be the correct answer. The physics data book also has the masses of particles expressed in the same units.

SL Q28

It is important for candidates to be aware of the difference between waves and tidal effects. Waves are primarily caused by wind (and therefore involve solar energy) while tides are caused by the pull of the Moon on the water.

Recommendations and guidance for the teaching of future candidates

Multiple Choice items are a motivating and highly time-efficient way of testing and promoting learning as a course is being taught. They can be used as warmers to stimulate discussion as well as for quick tests an*d* should never be regarded as add-ons to be practiced, a paper at a time, solely for the final examination session.

There is no single most successful strategy with MCQs, so flexibility of thinking is needed. The correct response may be found by elimination, by consideration of units, by use of simple proportion, or by ‘exaggeration’ – mentally allowing one of the quantities to get very much larger, or smaller. Occasionally simple factual recall is needed.

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. Frequently responses can be eliminated, either because they are transparently absurd, or because two responses are logically equivalent.

Graphs, force diagrams and other means of illustration are a fundamental way in which physicists seek to model and understand the world. Candidates should be encouraged to sketch their answers to problems before they plunge into calculations. There is evidence, also from the written papers, that this is not the case.

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.

Candidates can expect the proportion of questions covering a particular topic to be the same as the proportion of time allocated for teaching that topic, as specified in the Physics Guide.

Multiple choice items are kept as short as is possible. Consequently, all wording is significant and important. They should also bear in mind that they are asked to find the **best** response. Sometimes it may not be strictly 100% correct but Physics candidates should be used to identifying and ignoring quantities that have negligible impact.

Candidates should consult the current Physics Guide (March 2007) during preparation for the examination, in order to clarify the requirements for examination success. This Guide does invite the candidates to recall certain simple facts, although most of Physics is process orientated. Such facts lend themselves to Multiple Choice questioning so the teachers should not be afraid to require their candidates to occasionally memorise information. Definitions (which are universally poorly given in written papers) are perhaps best tested and learned with simple multiple choice questions.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 11	12 - 22	23 - 33	34 - 43	44 - 52	53 - 62	63 - 95

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 10	11 - 13	14 - 18	19 - 24	25 - 29	30 - 50

General comments

Thirty centres at HL [thirty two at SL] completed G2 forms. It continues to be a matter for regret by the examiners that there is such a poor return. Data and comments on the forms provide a valuable source of feedback during the grade award.

An overwhelming number regarded the HL paper as being appropriate in difficulty with 18 centres finding it of a similar standard to the previous year, 4 finding it a little easier and 7 finding it a little more difficult [at SL the numbers were 26;2;4] . The wording was regarded as very good by 13 centres with many of the remainder finding it either good or fair [SL 12]. Similar numbers were content with the presentation of the paper.

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

- Measurement and uncertainty
- Explanation of momentum changes
- Free-body diagram construction
- Fuel enrichment and energy transference
- Resonance in the context of the greenhouse effect
- Mechanism of formation of emission spectra

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

- Force calculations
- Electric field calculations
- Nuclear reactions and rest mass calculations
- Wave phenomena

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

Section A

Q1

(a) Draughtsmanship seemed better this year than previously with fewer double or hairy lines. There were however many straight lines drawn that failed to pass through all the error bars. These were sometimes accompanied by a comment in the next part question that a straight line passing through all the error bars could not be drawn.

(b) (i) Most the candidates were able to make a comment about the straightness of the line but few made reference to the error bars. Some tried to answer by attempting to discuss the physics of the situation (without reference to the graph as instructed).

(ii) About half the candidates scored 2 marks here. Some failed to extrapolate at all and performed a spurious trigonometric analysis to calculate an intercept. Most extrapolation estimates were quoted to 2 significant figures (sf) however some only quoted to 1 sf – this was accepted as a benefit of the doubt if the drawn line was close to a grid line. Examiners expect 2 sf accuracy in this type of question.

(c) This was poorly answered. The instruction “using your answer to (a)”, in other words, the line drawn, was ignored and many were plainly using inappropriate analyses that they had practised from previous papers. It is important for candidates to attempt each data analysis on its own merits. The analysis required varies from series to series.

Q2 [and SL Q4 part 2]

(a) [and SL (g)]

This was well answered. Candidates were clear what was required and expressed the physics well.

(b) [and SL (h)]

Two marks was a common score here. A common mistake was to omit the energy lost by the condensed steam cooling. A number of otherwise good candidates failed to omit the final calculation step and simply equated a long string of un-evaluated numbers to 1.8. This failure by candidates to "show" the complete working continues to be a problem.

(c) [and SL (i)]

The fact that energy was lost to the surroundings was frequently noted, but it was rare to see a complete and reasoned answer for the second mark.

Q3 [and SL Q5 part 2]

(a) [and SL (d)]

Too many candidates still believe that $R=V/I$ is a correct statement of Ohm's law rather than a definition of resistance. A clear explanation of how the graph shows that X is ohmic required both reference to the graph (straight *and* through the origin) and a correct interpretation of Ohm's law. The mark for Y was easier to gain and accordingly was often scored.

(b) and SL (e)

(i) Calculations of this straightforward piece of physics were poor. There were many power of ten errors caused either by arithmetic errors or mis-reading of graph scales. A value of 0.75 Ω rather than 750 Ω was commonly seen.

(ii) Again, this was marred by errors in physics. Two parallel branches with the same potential difference and equal resistance have the same current in each and therefore (in this case) the total current is 8 mA not 4 mA. The latter was the view of many candidates who had not appreciated fully the physics of the circuit.

(iii) [SL only] There were some good solutions often using errors carried forward from the previous parts.

Q4

(a) This was well answered with only a few quoting the value of *R* as a definition or writing a spurious definition in terms of energy per mole.

(b) This straightforward calculation was well done by many.

(c) A few candidates subtracted rather than added the 760 J but otherwise this was well done. A curious error by a good minority was to use a value for the volume of 3.6 x 10^{-3} m^{-3}.

(d) Most had the correct idea in this part question but then failed to gain full credit by leaving the examiner to make assumptions for the candidate about the physics. This was a particular problem for the award of the second mark. A repeat of the word “rapid” (in the question) cannot gain the credit; candidates must explain that the time for the compression is short and therefore the energy cannot be transferred out of the gas .

Q5

(a) (i) This was well answered by many with only a few errors.

(ii) The second marking point was often missed. A complete chain of argument was required. The speed of rotation of the loop is increased *so the time taken for one cycle is less* (this was frequently omitted) and the rate of change of flux with respect to time is therefore greater with (from Faraday’s law) a consequent increase in the emf.

(b) (i) Too many candidates talked about averaging a sine wave (zero over one cycle) and did not get to the heart of the explanation that the *same* heating effect is established from a direct current acting in a *resistor* and that the dc value is the rms of the ac value.

(ii) This was generally well done. Candidates knew which equation to use and manipulated the data well. Some however neglected the √2 in quoting the magnitude of the current.

Q6 [and SL Q2]

(a) This was poorly done. The direction and seat of the friction force were frequently wrong. The reaction force was mis-drawn. The labelling was poor. Weight was often called “gravity”. The inability of candidates to complete free-body diagrams continues to be an issue in the examinations.

(b) This part was, on the other hand, well done. Clearly candidates do not look at their diagram in answering the question as, had they done so, their signs would have been incorrect.

Section B

Q7 Part 1 [and SL Q4 Part 1]

(a) This was very well answered by many with no obvious common errors.

(b) [and SL (c)]
(i) The direction rules are clearly not understood as there were few correct answers here.
(ii) This was well answered.

(c) and (d) [and SL (d) and (e)]
These parts were well answered.

(e) [and SL (f)]
(i) Very many answers were too vague with candidates talking about (for example) the substance halving. Examiners expected candidates to focus on the number of *radioactive nuclei* or *atoms* decaying.
(ii) Well answered. Most candidates answered in terms of the decay of X rather than the growth of F-19. However, given an ambiguity in the question this was allowed.

Part 2 [HL only]

(f) Far too many candidates gave a definition that failed to convince that they were writing about a wave. Many also failed to convey the sense that relative motion between observer and source was involved.

(g) (i) Answers were very loose here. “Forwards”, “backwards”, “left” “right” were all seen and were of course all meaningless in the context of this question.
(ii) The calculations were well done but many went around in circles. The assumption that the speed of the star is much less than that of light was only rarely seen.

(h) (i) It was unusual to see a reference to a diffraction pattern and this failure lost a mark. Candidates must not assume that the examiner is going to provide this information for them. Also, a repetition of the fact that the images are “resolved” – another re-statement of the question – will not gain credit. It is important to make clear what the physics of the situation is.
(ii) The routine calculation of the separation of the two objects given the resolving angle and the wavelength was well done, with the usual smattering (and credit loss) of those who neglect the 1.22 factor in the Rayleigh equation.

Q8 Part 1 [and SL Q6 part 2; SL Q3]

(a) [and SL Q6(f)]
(i) This was well answered. There were only a handful of incorrect atmospheric gases quoted.
(ii) Candidates usually gave a well-rehearsed answer to the question “what is the greenhouse effect”. What was required here was a comparative treatment. Candidates must read the question and think about their response before launching into a pre-prepared paragraph.
(iii) [and SL Q3(a)] Most gained full credit here.

(b) [and SL Q3(b)] Candidates addressed the last two marking points very well and frequently gained both. However, the reasons focussing on the need for the removal of U-238 were poorly understood. Absorption by the more massive isotope was rarely quoted.

(c) [and SL Q3(c)]
(i) Most were able to calculate the mass of uranium required to raise the water temperature.
(ii) Again, many failed to read the question and left their answer in seconds rather than the required hours. A considerable number were unable to convert correctly from seconds to hours.

(d) [and SL Q3 ?]
Too many answers classified the energy transformations but failed to state the seat of the conversion (ie “in the turbine” etc). Some of these classifications were rudimentary in the extreme (eg “nuclear →heat→electrical” with little additional explanation). This will never score significant credit at this level.

Part 2 [HL only]

(e) This was answered well by many.

(f) (i) Few tangents were seen. Some candidates used coordinates in an attempt to carry through a gradient-like calculation. However the most common award was a mark of one for simply calculating the value of *V/R* at the specified position.
(ii) By contrast this simpler part question was answered well.

(g) Most gave the answer that the Moon is now further from the Earth although a few gave a more physical answer by attempting to explain the change in terms of the potential energy having become more negative.

Q9 Part 1 [and SL Q6 Part 1]

(a) This simple introduction was well answered.

(b) (i) Thoughts were not considered well enough before committing them to paper in this part. Few realised that the presence of the ice meant that no external force acts. Although the ball and object were described as moving in opposite directions, the underlying physics was only rarely well expressed. Too many assume that the ball was being thrown upwards and tried unsuccessfully to construct an answer in terms of vertical motion.
(ii) There were few statements of Newton’s second law and again there was much confusion about the physics. Linking arguments were missing. Candidates must be aware that examiners will not make links for them.

(c) This calculation was straightforward and well done by most.

(d) The chain of calculations in this (i) and (ii) was also well done by many although the units were often observed to be wayward.

(e) This was more problematic as candidates confused themselves as to the relevant energies to use (if they went down an energy route) or by mis-applying the kinematic equations and introducing power of ten or arithmetic errors into the calculation.

Part 2 [HL only]

(f) This was well answered, although some missed out the comparative nature of the answer by writing "they can hold a lot of data" which, of course, can be true for both analogue and digital stores.

(g) This was well answered. Most candidates were able to score two or (often) all three marks.

(h) (i) Very few focussed on the structure of the device but were much better at explaining the operation, going into much detail about later details of the process beyond the CCD itself. The "structure" had not been examined before and, again, candidates were guilty of making assumptions about what the question was examining.
(ii) The calculation of the length of an individual pixel often went wrong. However, candidates could recover from this by making a correct judgement on resolution based on the answers they had gained.

Q10 Part 1 [and SL Q5 Part 1]

(a) Both parts of (a) [(i) in SL] were well answered.

(b) (i) This was very simple and accordingly well done.
(ii) and (iii) These were either well or poorly done with no half measures. Those candidates who knew exactly what they were doing obtained the correct answer, others cast around for suitable equations, failed to find them, and gave up.

(c) (i) It was often unclear what was vibrating, let alone what was its direction of motion. There was often a reference to the propagation of the energy however. This standard piece of bookwork should have been done much better by many candidates.
(ii) This was well answered.
(iii) [SL only] Some candidates inverted the correct equation (gaining some credit). Solutions were usually poorly explained.

Part 2 [HL only]

(d) (i) Candidates who provided a labelled diagram tended to be more successful as they often had a screen or viewing device on them whereas written answers usually omitted this. Some candidates confused absorption and emission spectra and gained few or zero marks in consequence.
(ii) The explanation here was usually vague with many simply re-stating the stem of the question. It is clear that the arguments involved in this part of the syllabus are not well appreciated with only a hazy understanding of the physics.

(e) (i) This was well done with only a few candidates omitting the negative sign.
(ii) This was usually answered by a reverse argument beginning with the wavelength and working towards the value of *n*. This could achieve full marks, but many candidates could not cope with the multi-step problem and gave up after arriving at the energy associated with $n = 4$.

(f) This was poorly answered. It was rare to see a good account of the energy distribution although occasionally the sharing of the total emitted energy was credited.

Recommendations and guidance for the teaching of future candidates

- Candidates should be taught for understanding rather than rote learning. Definitions should be understood so that specific details are omitted under the pressure of examination.
- More practice with data analysis questions.
- Questions about the greenhouse effect continue to be poorly answered.
- Use mark schemes in preparation and consult subject reports for details of areas where candidate performance is poor.
- Simple algebraic transformations and ability to handle powers in equations.
- Learn to use reading time wisely and to read questions carefully and accurately.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 22	23 - 28	29 - 33	34 - 39	40 - 60

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 13	14 - 17	18 - 22	23 - 26	27 - 40

General Comments

Almost the full range of marks was seen at both HL and SL, with the vast majority of candidates appearing to have sufficient time to complete their answers. Some of the feedback from teacher's comments on the G2 forms is summarised below. These comments are appreciated by question setters and are taken into account during the grade award.

At HL, Option E (Astrophysics) is the most popular option, closely followed by G (Electromagnetic waves), I (Medical Physics), H (Relativity) with relatively few centres attempting F (Communications) or J (Particle physics).

At SL, Options A (Sight and wave phenomena), E (Astrophysics), B (Quantum Physics) and G (Electromagnetic waves) continue to be the most popular, whilst options C (Digital technology), D (Relativity and particle physics) and F (Communications) are chosen by far fewer candidates.

Higher Level G2 feedback

26 centres found the level of paper difficulty appropriate. 3 centres thought it too difficult. 1 thought it too easy.20 centres thought the paper was of the same standard as last year. 8 centres thought it more difficult. 1 centre thought it easier than last year. Of the 30 centres responding, 1 centre thought that the clarity of wording was poor and none thought that the presentation of the paper was poor. The remaining centres thought that these were satisfactory to excellent.

Standard Level G2 feedback

All 32 centres responding found the level of difficulty appropriate. 21 centres thought the paper was of the same standard as last year. 9 centres thought it more difficult. 2 thought it easier than last year. All centres thought that the clarity of wording was satisfactory to excellent. 1 centre thought that the presentation of the paper was poor. This was due to the new question numbering system. 31 centres thought that the presentation was satisfactory to excellent.

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

General difficulties (HL and SL)

- Highlighting key phrases or data in a question.
- Crossing out work that is correct and not replacing it with an alternative answer.
- Knowing what the symbols represent in a data book formula or equation.
- Powers of 10 and unit prefixes.
- Careless arithmetic and algebraic errors. Calculator mistakes are far too common.
- Failing to choose widely separated points in gradient measurement.
- Showing working in 'show that' questions. Always show more significant digits than are given.
- General layout of working in numerical questions - needs to be planned and methodical.
- Sequencing the presentation of facts to support an explanation or description.
- Use of a ruler in drawing diagrams. Even for sketches it can be very helpful.
- Paying attention to specific command terms - determines, explain, estimate, outline etc.
- Paying attention to the number of marks awarded for each part question. Often candidates provide fewer key facts than required.
- Stating definitions in standard format.
- Mis-interpreting the question and answering an 'imagined' or ‘assumed’ question.

Higher level difficulties

- Knowledge of the direction of the Earth's rotation.
- Apparent and absolute magnitudes of stars - particularly the reverse scale.
- The difference between stellar and spectroscopic parallax.
- Estimating stellar relative luminosity from absolute magnitude data.
- Failure to refer to galaxies in describing astrophysical red shifts.
- Power of ten errors in questions involving Hubble's constant.
- FM bandwidth.
- Explanation of time-division multiplexing.
- The Schmitt trigger.
- The different roles of the base station and the cellular exchange in mobile communication.
- Thin film interference calculations.
- Relativistic kinematics, especially simultaneity and time dilation.
- Relativistic mechanics, especially the use of the units MeV, $MeVc^{-1}$ and $MeVc^{-2}$.
- Use of the inverse square law.
- Understanding of, and differences between, radiation therapy and diagnosis.
- Changing eV to J in dosimetry calculations.
- Synchrotron operation and the changes needed to the E and B fields.
- Explaining nucleosynthesis and the conditions for it in the early universe.

Standard level difficulties

- Doppler effect calculations.
- Resolution – drawing diffraction patterns.
- Photoelectric effect (wave theory and Einstein model).
- Charge-coupled devices.

- The Schmitt trigger.
- Relativistic kinematics, especially simultaneity and time dilation.
- Knowledge of the direction of the Earth's rotation.
- Apparent and absolute magnitudes of stars - particularly the reverse scale.
- The difference between stellar and spectroscopic parallax.
- FM bandwidth.
- Explanation of time-division multiplexing.

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

The best candidates have fully covered the syllabus, show good understanding, can manipulate equations, take care with units, show all working in a methodical way and explain concepts with clarity. The weakest candidates often fail to read the whole question, have poor knowledge of concepts, lack conciseness and clarity in answers, are reckless with units, don't show all working or use the wrong equation. Clearly many candidates have studied past papers and are able to demonstrate good knowledge of the commonly tested parts of the syllabus. Candidates often perform far better with calculation questions than with questions requiring recall of laws, definitions, experiments and concepts. Weaker candidates may score all of their marks on calculations, which possibly indicate that this is the type of question with which they are most familiar. Options A, B, E, and G at SL and E, G, I and H at HL are very popular and most candidates make a good effort to tackle these questions.

Noted improvements at HL

- Very few candidates answering fewer or more than two Options.
- Keeping responses within the answer box provided.
- Referring to the use of an extension sheet within the answer box.

Some improvement in knowledge or understanding were seen in the following syllabus

areas:

- Interpretation of HR diagrams.
- Knowledge of the Chandrasekhar limit.
- Dispersion in optical fibres.
- Explaining chromatic aberration.

- X-ray spectra explanations.
- Attenuation coefficient calculations.
- Calculations involving decibels.
- Dosimetry calculations (but see difficulties above)
- Interpretation of Feynman diagrams.

Noted improvements at SL

- Accommodation of the eye.
- Doppler effect description.
- Planck constant and work function calculations.
- Completion of nuclear equations.
- Half-life calculations.
- CCD calculations.
- Compact disks.
- Interpretation of Feynman diagrams.
- Calculations with stellar luminosity.

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

Higher Level (questions marked * were also on the SL paper)

Option E. Astrophysics

The most popular option..

*__1. Stars -__ In (a) very few candidates stated that the Earth rotates from west to east. (b) is an easy standard question. In (c)(i) many mis-understood the question, but others were able to calculate the distance of Lutyens star or explain why it must be closer than 10pc from Earth. In (c)(ii) the range for **stellar** parallax (as opposed to the required spectroscopic parallax) was most often given. The star calculations in (d)(i), (d)(ii) and (d)(iii) were done quite well by the majority of candidates. Quite a large number of candidates used data for the wrong star or confused apparent and absolute magnitudes. Some silly arithmetic mistakes were evident and there were many who did not provide evidence of working to 2 or 3 significant figures in the 'show that' question in (d)(ii). There are, as usual, candidates who do not know that A, in the S-B formula, is for the surface area of a sphere, although on this occasion it did not matter. The value of the Chandrasekhar limit was often correctly stated in (d)(iv). In (e) most could place star G correctly but were less certain about star L. A dot should be used to indicate HR star positions rather than a large letter.

***2. Newton's Universe -** In (b) candidates often failed to mention **galaxies** when discussing red shifts, or failed to refer to the **light** being red-shifted. 'Stars are red-shifted' was a common invalid response.

3. **Red-shift -** No major problems with the graph in (a) (ruler use not always seen!) , but in (b) there were often power of ten errors in the use of Hubble's constant. Power of ten errors are penalised - some candidates obviously think otherwise.

Option F. Communications

***4. Frequency modulation -** Candidates often failed to refer to, or distinguish between, the carrier wave and signal wave in (a). Very few could attempt the calculation expected in (b)(ii). This was a 'determine' question but most just 'discussed' frequency variation in a non-numerical way. In (c) very few candidates could use the data table to calculate the bandwidth - the markscheme allowed either 36 or 48 MHz. Most incorrectly gave twice the signal frequency, which is only correct for AM.

***5. Signal Transmission** - In (a)(i) most candidates correctly referred to dispersion, although not necessarily to modal or material dispersion. Failure to refer to the power-time graph was very common in (a)(ii). In (b) the details of time-division multiplexing were often very sketchy and often all that was effectively stated was that many signals were sent together. This is a good example of a question where bullet points can be used in an answer. Part (c) was well answered by the majority, most choosing to mention time delay, energy to get into orbit, or regions of the Earth that were accessible. Some SL candidates made vague comments about the effective footprint of polar-orbiting and geostationary satellites.

***6. The Schmitt trigger** - All parts of this question were very poorly answered with very few candidates referring to the behaviour of the circuit for a range of values of V_{in}. Even though the markscheme was generous, in terms of allowing alternative approaches to the calculation of switching voltages, hardly any correct answers were seen.

***7. Mobile phones -** As usual few candidates answered the specific question asked. There is still confusion about the term 'cellular exchange'. Many believe the latter to be a process rather than a telephone exchange (mobile switching centre) which controls the base stations. See syllabus section F6.2.

Option G. Electromagnetic waves.

This option is almost as popular as Astrophysics.

***8. The Microscope -** The ray diagram in part (a) was drawn correctly by the vast majority of HL candidates, with a few showing unnecessary refraction at the objective lens. Not all candidates used rulers. At SL a number of candidates were unaware of which rays to draw to successfully locate the image. Both image calculations in (b) were done well, although a few candidates used the telescope magnification for (b)(ii). Part (c) was generally well done.

***9. Wave properties -** In (a) candidates were expected to refer to addition of displacement rather than amplitude. (b)(i) was an easy 3 marks for explaining 2 slit interference, although few made use of annotations to the diagram. In (b)(ii) most could state the effect of doubling the wavelength, but could not explain it very coherently. Many of those quoting the double slit formula failed to mention the variables that were held constant and therefore failed to obtain full marks. Part (c), about increasing the number of openings, is commonly asked and was well answered. Surprisingly there were several candidates who referred to 'amplitudes' instead of 'maxima'.

10. X-Rays – (a)(i) was almost always correctly answered. The X-ray spectrum was usually well drawn, but quite often the non-zero wavelength cut-off was forgotten. As expected there were candidates who failed to use any annotation. In (b) the origins of the characteristic spectrum were well described, although too many candidates mentioned excitation rather than ejection of inner shell electrons.

11. Wedge fringes - The diameter of a hair calculation in (a) was done moderately well. However, many candidates tried to use the double slit interference formula or overlooked the return path of the wave between the slides and so obtained twice the correct answer. Almost nobody could work out how the fringes would change in (b). Many incorrectly assumed that curved fringes would appear rather than a change in spacing.

Option H. Relativity

***12. Time dilation and relativistic mass -** In (a) most candidates knew what was meant by a frame of reference, although many described it as a 'point' in space. The calculations of elapsed time in the two reference frames were usually correct in (b), with the usual number of candidates getting them the wrong way round. Most knew that S measures the proper time for the journey between X and Y; far fewer knew that this was because S's clock was at both events. Many stated that it was because S's clock was at rest - which shows a basic mis-understanding of the whole concept of relative motion. In (b)(iv) very few candidates could explain that the lack of simultaneity was due to the different distances and times that the two signals took to reach X and Y as determined from the S frame. As usual most incorrectly referred to the signals **reaching** S.

HL only: The mass of the spaceship was an easy 2 marks in (c)(i) as was the graph of mass vs speed in (c)(ii). Part (d), concerning muons, rarely gained candidates all 3 marks. Most did not refer to the situation in (b) or stated that 'time runs slow **for** the muons' - a common mistake, as the correct way of looking at this is to say that 'the muon's time runs slow **for** the Earth observer'. (Teaching note: Candidates find this easier to grasp if numerical data are used. This example is based on $\gamma=5$ and an elevation difference of 3000m. Assume that, nonrelativistically, the muon half life is 2μs and the (improper) journey time is 10μs. So 3% of muons would survive. But relativistically the half life is dilated to 10μs in the Earth frame and the proper journey time is only 2μs in the muon frame. So with time dilation, in either frame, 50% of the muons survive. The data can be presented in the form of a table or used as the basis of a question).

13. Relativistic energy and momentum - (a) was found to be difficult for many candidates who tried to work in kg. For those that worked in MeV the 3 marks were easily obtained. The calculations of proton speed and momentum in (b) were often correct, but again with occasional problems with units.

14. Spacetime - In (a) many candidates described the properties of spacetime rather what it means in terms of x,y,z,t coordinates. (b)(i) and (b)(ii), concerning the effect on spacetime of the sun or black holes, were well answered by most.

Option I. Medical Physics

15. Hearing - (a) and (b)(i) were well answered, although many candidates forgot to mention that hearing loss is age related. Some, who did know this, still chose the wrong graph. In (b)(ii) the 15dB intensity level difference was used by almost all candidates, but there were many opportunities for arithmetic errors along the way. An encouraging number of candidates scored full marks.

16. Medical imaging - When defining attenuation coefficient it is expected that all symbols used will be explained**.** Part (b)(i), a calculation of intensity ratio for two X-rays, was done remarkably well. Almost all candidates realised that the effect of the tooth enamel could be ignored as it was the same for both rays. This was a 'show that' question and some candidates failed to get the final mark because they did not **show** more significant figures than is already given in the question. (b)(ii) was more difficult as most could not explain that the contrast at A would be poor because of underexposure or because the fillings's attenuation is so much greater than that for the enamel that fine details in the enamel will not be visible. In (c) candidates realised that the procedure would be safer for one mark. The second mark, for saying that it would be quicker, was usually missed. (d), concerning ultrasound imaging, was done very well. Most candidates seem well aware that reflection of ultrasound increases with increasing difference between the acoustic impedances at a boundary.

17. Oximetry - A well answered question, although some candidates missed the fact that two different frequencies were used and the absorptions compared.

18. Radiation in medicine - (a)(i) was more difficult than expected. Many failed to realise that physical decay would be almost complete in five days. In (a)(ii) many were able to get 2 marks by referring to the RBE of alphas, or to their short range, or to the short half-life. Part (b), concerning dosimetry, was generally well answered. The major stumbling block was expressing the alpha particle energy in Joules. Error carried forward (ECF) was usually needed to obtain 2 marks out of 3 for the dose equivalent.

Option J. Particle Physics.

Relatively few candidates chose this option.

***19. Particles -** In (a) particles X and Y were usually correctly identified as was the pi meson. To get the second mark in (a)(iii) candidates needed to refer to the meson being, for example, a boson, being unstable, being its own antiparticle etc. Finding the mass of X in $MeVc^{-2}$ was found to be difficult and usually only 1 mark was obtained for some algebra. The simple Feynman diagram in (c) was well done by most, as were both parts of (d) concerning conservation of strangeness. (SL: In general SL candidates were not referring to the change in strangeness although a small number made reference to the weak interaction).

20. The synchrotron - In (a)(i) most candidates could explain the role of the electric and magnetic fields. However, in (a)(ii) very few could explain why the frequency of the electric field increases and the magnitude of the magnetic field increases. (b) was a demanding question but an encouraging number of candidates scored 3 marks for correctly calculating the value of B. Part (c), about international cooperation, was an easy 2 marks for many.

21. Scattering - The markscheme was generous and gave far more marking points than the four available. Nevertheless few candidates mentioned deep inelastic scattering (or even proton-proton scattering which was permitted by the markscheme).

22. Nucleosynthesis - The whole question was poorly answered. Very few could explain either nucleosynthesis or the need for a definite range of temperatures to sustain it.

Standard level paper three

Option A. Sight and wave phenomena

The most popular option at SL.

1. Accommodation - Both parts were quite well answered, but often without any mention of focusing in (a) or focal length in (b) and therefore not providing a complete response. The change in size of the pupil was occasionally mistakenly referred to. Contraction and relaxation of the ciliary muscle were sometimes confused and specific reference to ciliary muscles was often missing.

2. Doppler effect - (a) was usually answered correctly although candidates need to be clear it is a perceived/observed change in frequency and not an actual change. In (b) there were many correct answers, but sometimes the wrong Doppler equation was used or an incorrect sign convention chosen. A small number of candidates were able to substitute values in the equation but had difficulty with solving for v.

3. Scattering and polarisation - Some improvement in the answers to (a), concerning the conditions for image resolution, was noted. Many candidates scored 2/3 or 3/3. However, there were still a number of poorly drawn diagrams to show the case of the two images being just resolved. In (b) fewer candidates omitted to use the factor of 1.22 and full marks were often scored. A common mistake was to get confused between radians and degrees. Part (c), concerning the meaning of polarisation, was easy although a number did not refer to the electric/magnetic field. (d) was straightforward although many forgot to give the complement of the Brewster angle.

Option B. Quantum physics and nuclear physics

4. Photoemission - In (a), as in previous sessions, few candidates could organise their answers in a systematic way. The effect of increasing light intensity was often overlooked as was the existence of a threshold frequency. Many candidates stated that energy depends on the frequency but without stating that they are proportional. Both calculations in (b) were quite well done by many candidates and the experience of trying past papers was evident. There were a few power of ten errors from candidates who believe that, because final unit errors are not penalised, they need not worry about powers of ten. A number failed to read the scale on the graph correctly or chose two points which were close together leading to answers outside of the allowed range. Part (c) produced fewer correct answers, but a number of candidates could produce the formula relating de Broglie wavelength and particle energy and were able to calculate the electron kinetic energy. Candidates need to be reminded that in ‘show that' questions they should be giving their answer to at least one more significant figure than is given in the question.

5. Radioactivity - (a) was very easy with most candidates scoring both marks. Very few candidates could determine the original number of K-40 atoms in (b). ECF was usually needed for any marks to be gained apart from for the determination of the decay constant. A number of candidates tried making an estimate of the number of half-lives but this was usually unsuccessful.

Option C. Digital technology

This option was chosen by few candidates.

6. CCD and CDs. The fact that pixels act as capacitors was often overlooked in (a). Almost all candidates could determine that 293 pictures could be stored in (b). (c) is a frequently asked question and was well answered.

Questions from 7 onwards were also on the HL paper 3. They are marked with * in that section. However there were 2 unique SL parts within questions 7 to 16:

Option F, Q14.(a)(ii) Most of the few answers seen correctly mentioned pulse overlap.

Option G, Q16.(b)(i) Very few mentioned that both waves originated from the same wave front and did not appreciate what the question was referring to.

Recommendations and guidance for the teaching of future candidates (HL and SL)

The option topics allow candidates to experience some of the more challenging and interesting areas of Physics. However the importance of the fundamental principles of the subject should not be underestimated. Definitions and statements of laws are sometimes poorly expressed or largely guesswork. In general candidates tend to perform less well on the descriptive parts of questions, these are often the cause of the difference between a mediocre and a good candidate. In setting private study exercises it is helpful for candidates to be given not only numerical questions but also plenty of extended response questions which are marked rigorously.

A common misconception is that units do not matter - because the incorrect or missing unit in a final answer is usually not penalised. This is a dangerous assumption because mistakes with units, within the calculation, will obviously lead to an incorrect numerical value or power of 10 error. These mistakes **are** penalised. Rigorous treatment of units is an essential part of any Physics course.

Past papers provide the opportunity for essential practice with the style of questions candidates will face. Giving candidates model answers (as well as past markschemes) allows them to understand the level of response that is expected. These are often provided in IB Physics textbooks. The marking of key phrases in a question should be encouraged as so often an instruction or piece of information is missed. The mark for a question, given in the margin of the paper, is a useful indicator of the detail required in a response.

All candidates should be given the full IB Physics Subject Guide and Data Booklet. Both are essential learning tools and very useful as revision checklists. The subject guide and data booklet can be provided in teacher-annotated form, with textbook page references, web-site links and past paper question references. Although time consuming, it is so easy to do since both documents are in digital format. If they cannot be provided in this form at the beginning of the course, then the annotations can be added by candidates as the course progresses. Teachers are advised to have sessions, during revision, to explain the use of every equation and all items of data in the Data Booklet.

G2 comments often complain that questions test information that is not in the Subject Guide. For example the relationship between stellar luminosity and absolute magnitude, or the function of the ciliary muscles (at SL). It is important to remember that the Subject Guide provides a framework, a list of aims, objectives and assessment statements - it is not meant to be a definitive list of facts. There are several excellent IB textbooks that interpret the various objectives. Physics department's schemes of work will usually make use of many additional online sources of information. IBO's OCC, Wikipedia, Hyperphysics, CERN, NASA, Physics.org, outreach.atnf.csiro.au, phys.unsw.edu.au, etc. Provide a wealth of relevant and inspirational material. These can be organised by teachers into a very valuable learning resource, to supplement textbooks, in the teaching of each of the options (as well as the Core).