# Physics Time Zone 1

## Overall grade boundaries

### Higher level

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 15 | 16 - 28 | 29 - 38 | 39 - 48 | 49 - 59 | 60 - 69 | 70 - 100 |

### Standard level

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 14 | 15 - 26 | 27 - 38 | 39 - 47 | 48 - 58 | 59 - 68 | 69 - 100 |

## Time zone variants of examination papers

To protect the integrity of the examinations, increasing use is being made of time zone variants of examination papers. By using variants of the same examination paper candidates in one part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the examination papers. For the May 2014 examination session the IB has produced time zone variants of Physics HL/SL papers.

## 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 |



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# 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 May 2014 exam session proceeded with no significant difficulties. The majority of centres performed established assessment investigations and provided detailed assessment comments and notation. This was most helpful to the moderators. The majority of candidate reports were word-processed and graphs were drawn with graphing programs.

# The range and suitability of the work submitted

Most centres had a comprehensive practical program and teachers were assessing appropriate work. However, more and more centres are assigning only two investigations for assessment, and this limits the candidate's chances of earning higher marks. There was wide use of ICT and many traditional labs are being carried out. One trend unique to this exam session is that a few centres were assigning computer simulations for a three criteria assessment lab. Although using a simulation is not forbidden candidates and teachers must be very careful to ensure that the chosen simulation can achieve the aspects of the assessed criterion.

# Candidate performance against each criterion

## Design (D)

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 like gravity or the specific heat capacity of an unknown liquid. Candidates need to be reminded that for a complete under design that variables need to be defined (and vague statements 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)

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.

### 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 candidates can help each other with the physical manipulation of equipment.

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, especially when expressing the gradient and its uncertainty for linear graph lines.

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. For this reason, candidates should not be assessed for CE when performing a traditional and established high school investigation.

## 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.

The following sections contain the advice that physics IA moderators follow.

## When moderators mark down

### Design

The moderator will mark down when the teacher gives a clearly defined research question and/or the independent and controlled variables. The teacher may give the candidate the dependent variable (as long as there are a variety of independent variables for the candidate to identify). Giving the candidate the general aim of the investigation is fine if the candidate has significantly modified the teacher prompt or question (e.g. made it more precise, defined the variables). The moderator will mark down when a method sheet is given which the candidate follows without any modification or all candidates are using identical methods. Standard laboratory investigations are not appropriate for assessment under Design.

### Data Collection and Processing

The moderator will mark down when a photocopied table is provided with headings and units already complete, for candidates to fill in. If the candidate has not recorded uncertainties in any quantitative data then the maximum given by the moderator is “partial” for aspect 1. If the candidate has been repeatedly inconsistent in the use of significant digits when recording data then the most a moderator can award is “partial” for aspect 1. In physics, data is always quantitative. Drawing the field lines around a magnet does not constitute DCP.

The moderator will mark down when a graph with labelled axes is provided (or candidates have been told which variables to plot) or candidates follow structured questions in order to carry out data processing. For assessment under DCP aspect 3, candidates are expected to construct graphs. For a complete, the data points on the graph should include uncertainty bars, and the uncertainty in the best-straight line gradient needs to be calculated.

### Conclusion and Evaluation

If the teacher provides structured questions to prompt candidates through the discussion, conclusion and criticism then, depending on how focused the teacher’s questions are and on the quality of the candidates responses, the maximum award is partial for each aspect that the candidate has been guided through. The moderator judges purely on the candidates input. The difference between a partial and a complete for CE aspect 1 involves the justification of their interpretation of the experimental results. This is a difficult task, and it can involve physical theory.

## When moderators do not mark down

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

### Design

Moderators do not mark down when the independent and controlled variables have been clearly identified in the procedure but are not given as a separate list (we mark the whole report and there is no obligation to write up according to the aspect headings). Moderators do not mark down when there is a list of variables, and it is clearly apparent from the procedure which variable is independent and which is controlled.

Moderators do not mark down when similar (but not word for word 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, they give credit for equipment clearly identified in a stepwise procedure. Remember, moderators look at the whole report. Moderators do not insist on ± precision of apparatus to be given in the apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DCP. Moderators do not downgrade a teacher’s mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Moderators support the teacher’s stance here.

## Data Collection and Processing

In a comprehensive data collection exercise possibly with several tables of data, if the candidate has been inconsistent with significant digits for just one data point or missed units out of one column heading, then the moderator will not mark this minor error down. If the moderator feels the candidate 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 good candidates responding in full to an extended task are unfairly penalized more often than candidates addressing a simplistic exercise. The candidate is not marked down if they have not included any qualitative observation(s) and the moderator cannot think of any that would have been obviously relevant. The moderator does not mark down if there is no table title when it is obvious what the data in the table refers to. Often candidates do all the hard work for DCP and then lose a mark from the teacher because they did not title the table. Except for extended investigations it is normally self-evident what the table refers to.

The expectation for the treatment of errors and uncertainties in physics is described in the Subject Guide and the TSM. Both SL and HL candidates are assessed on the same syllabus content and the same standard of performance.

All raw data is expected to include units and uncertainties. The least count of any scale or the least significant digit in any measurement is an indication of the minimum uncertainty. Candidates may make statements about the manufacture’s claim of accuracy, but this is not required. When raw data is processed, uncertainties need to be processed (see the Subject Guide, assessment statement 1.2.11).

Candidates 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.

Minimum and maximum gradients should be drawn on linear graphs using uncertainty bars (using the first and last data points) for only one quantity. This simplified method becomes obscured when both graph quantities contain uncertainty bars. Other uncertainty analysis is expected when graphs are non-linear.

If the candidate has clearly attempted to consider or propagate uncertainties then moderators support the teacher’s marking even if they may feel that the candidate could have made a more sophisticated effort. If propagation is demonstrated in part of the lab then full credit can be awarded even if error analysis is not carried through in every detail (as long as the candidate has demonstrated an appreciation of uncertainty then they can earn a complete).

Moderators do not punish a teacher or candidate if the protocol is not the one that is taught i.e. top pan balance uncertainties have been given as ± 0.01g when teachers may feel that if the tare weighing is considered then it should be doubled. Moderation is not the time or place to establish a favoured IB protocol.

## Conclusion and Evaluation

Moderators often apply the principle of “complete not meaning perfection”. For example, if the candidate has identified the most sensible sources of systematic error then the moderator can support a teacher’s marking even if the moderator can identify one more. Moderators are a bit 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 they will comment on the 4/IAF as to the unsuitability of the task giving full justifications. This will be provided in feedback but the moderator will not necessarily downgrade the candidate. Yes, this does mean that candidates could get high DCP marks for quite brief work on limited data but, if they have fulfilled the aspects requirements within this small range, then the moderator will support the teacher’s marks.

The most challenging aspect of CE is the differentiation between a partial and a complete under aspect 1: “States a conclusion, with justification, based on a reasonable interpretation of the data.” A justification may be a mathematical analysis of the results, one that includes an appreciation of the limits of the data range, but it might also be an analysis that includes some physical meaning or theory, even a hypothesis (though a hypothesis is not required). It is difficult to earn a complete in CE (aspect 1) because serious and thoughtful comments are required, something beyond “the data reveals a linear and proportional relationship”.

## Higher level paper one

### Component grade boundaries

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 10 | 11 - 13 | 14 - 16 | 17 - 20 | 21 - 23 | 24 - 27 | 28 - 40 |

## Standard level paper one

### Component grade boundaries

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 7 | 8 - 10 | 11 - 14 | 15 - 16 | 17 - 19 | 20 - 21 | 22 - 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.

Every year there are occasional comments from teachers that either paper 1 or paper 2 are unbalanced in terms of syllabus cover. It should be noted, however, that these two papers together aim to provide valid assessment of the complete syllabus, both in content and skills. The specific skills that need to be encouraged in the candidates in order to succeed at multiple choice questions are described in the final section of this report.

Only a small percentage of the total number of centres returned G2's. For SL there were 67 responses from 500 centres and for HL there were 42 responses from 294 centres. While we would like to thank those who took the trouble to provide G2 feedback, we would urge all centres to contribute; comments from teachers are carefully considered.

The replies received indicated that the papers were generally well received, with many of the G2's containing favourable comments, despite a general feeling that the paper was difficult. About half of the teachers felt that they contained questions of an appropriate level and generally in line with last year's papers, although 50% found the HL paper (but only 33% the SL paper) more difficult than the May 2013 paper.

With few exceptions, teachers thought that the presentation of the papers and the clarity of the wording were either satisfactory or good. There were some comments to the effect that some of the questions were too wordy for second language candidates.

### 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 | 2567 | 400 | 271 | 286 | 6 | 72.72 | 0.4 |
| 2 | 37 | 1940 | 843 | 701 | 9 | 19.86 | 0.16 |
| 3 | 421 | 154 | 1644 | 1310 | 1 | 37.11 | 0.55 |
| 4 | 1220 | 178 | 1951 | 167 | 14 | 55.27 | 0.55 |
| 5 | 130 | 3226 | 123 | 49 | 2 | 91.39 | 0.07 |
| 6 | 749 | 1849 | 722 | 195 | 15 | 52.38 | 0.54 |
| 7 | 103 | 356 | 2547 | 522 | 2 | 72.15 | 0.43 |
| 8 | 2260 | 628 | 437 | 198 | 7 | 64.02 | 0.42 |
| 9 | 212 | 1513 | 527 | 1241 | 37 | 42.86 | 0.43 |
| 10 | 1157 | 123 | 171 | 2074 | 5 | 58.75 | 0.58 |
| 11 | 158 | 959 | 2180 | 219 | 14 | 61.76 | 0.51 |
| 12 | 247 | 1280 | 318 | 1678 | 7 | 47.54 | 0.18 |
| 13 | 1103 | 774 | 768 | 869 | 16 | 31.25 | 0.28 |
| 14 | 607 | 1188 | 667 | 1042 | 26 | 18.9 | 0.09 |
| 15 | 839 | 1079 | 1179 | 426 | 7 | 23.77 | 0.33 |
| 16 | 415 | 2090 | 802 | 204 | 19 | 59.21 | 0.57 |
| 17 | 1600 | 995 | 744 | 186 | 5 | 45.33 | 0.41 |
| 18 | 1229 | 1248 | 362 | 685 | 6 | 19.41 | 0.14 |
| 19 | 1574 | 575 | 955 | 413 | 13 | 44.59 | 0.38 |
| 20 | 146 | 1581 | 458 | 1337 | 8 | 37.88 | 0.48 |
| 21 | 202 | 1696 | 1437 | 188 | 7 | 48.05 | 0.34 |
| 22 | 1049 | 1513 | 380 | 583 | 5 | 16.52 | 0.18 |
| 23 | 1053 | 55 | 927 | 1490 | 5 | 42.21 | 0.28 |
| 24 | 1360 | 918 | 447 | 800 | 5 | 38.53 | 0.25 |

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 25 | 1859 | 369 | 1097 | 201 | 4 | 10.45 | 0.14 |
| 26 | 95 | 130 | 3166 | 131 | 8 | 89.69 | 0.21 |
| 27 | 197 | 2297 | 321 | 706 | 9 | 65.07 | 0.39 |
| 28 | 115 | 2983 | 211 | 211 | 10 | 84.5 | 0.2 |
| 29 | 1757 | 138 | 1437 | 187 | 11 | 40.71 | 0.4 |
| 30 | 310 | 463 | 2193 | 544 | 20 | 62.12 | 0.37 |
| 31 | 1054 | 917 | 803 | 733 | 23 | 29.86 | 0.26 |
| 32 | 1341 | 727 | 965 | 456 | 41 | 37.99 | 0.55 |
| 33 | 382 | 2070 | 853 | 190 | 35 | 58.64 | 0.28 |
| 34 | 874 | 392 | 186 | 2036 | 42 | 57.68 | 0.55 |
| 35 | 118 | 283 | 953 | 2160 | 16 | 61.19 | 0.37 |
| 36 | 1362 | 1368 | 507 | 249 | 44 | 38.58 | 0.26 |
| 37 | 152 | 804 | 1118 | 1405 | 51 | 39.8 | -0.18 |
| 38 | 550 | 607 | 1281 | 1029 | 63 | 29.15 | 0.42 |
| 39 | 631 | 1982 | 691 | 195 | 31 | 56.15 | 0.47 |
| 40 | 167 | 2077 | 293 | 957 | 36 | 58.84 | 0.3 |

Number of candidates: 3530

## SL paper 1 item analysis

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 1 | 550 | 1817 | 2290 | 1710 | 21 | 35.85 | 0.43 |
| 2 | 4028 | 776 | 817 | 752 | 15 | 63.06 | 0.45 |
| 3 | 101 | 268 | 429 | 5572 | 18 | 87.23 | 0.24 |
| 4 | 3205 | 447 | 2435 | 261 | 40 | 38.12 | 0.47 |
| 5 | 340 | 5612 | 288 | 133 | 15 | 87.85 | 0.12 |
| 6 | 481 | 5258 | 451 | 165 | 33 | 82.31 | 0.33 |
| 7 | 148 | 239 | 5408 | 575 | 18 | 84.66 | 0.27 |
| 8 | 1946 | 2348 | 1589 | 458 | 47 | 36.76 | 0.45 |
| 9 | 915 | 3559 | 962 | 911 | 41 | 55.71 | 0.26 |
| 10 | 2748 | 473 | 456 | 2697 | 14 | 42.22 | 0.49 |

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 11 | 319 | 2442 | 2935 | 670 | 22 | 45.95 | 0.50 |
| 12 | 1156 | 2706 | 1137 | 1318 | 71 | 17.80 | 0.02 |
| 13 | 899 | 2671 | 1946 | 859 | 13 | 14.07 | 0.21 |
| 14 | 1734 | 1868 | 1666 | 1103 | 17 | 29.24 | 0.33 |
| 15 | 1169 | 2736 | 1848 | 598 | 37 | 42.83 | 0.40 |
| 16 | 1678 | 249 | 3956 | 485 | 20 | 61.93 | 0.41 |
| 17 | 349 | 2837 | 2890 | 284 | 28 | 44.41 | 0.23 |
| 18 | 1658 | 3367 | 445 | 905 | 13 | 14.17 | 0.10 |
| 19 | 351 | 771 | 2419 | 2818 | 29 | 44.11 | 0.22 |
| 20 | 2272 | 1911 | 872 | 1312 | 21 | 35.57 | 0.23 |
| 21 | 3028 | 646 | 1935 | 749 | 30 | 47.40 | 0.52 |
| 22 | 373 | 3865 | 770 | 1344 | 36 | 60.50 | 0.37 |
| 23 | 1010 | 579 | 4487 | 300 | 12 | 70.24 | 0.42 |
| 24 | 390 | 5284 | 381 | 299 | 34 | 82.72 | 0.30 |
| 25 | 1865 | 996 | 553 | 2886 | 88 | 45.18 | 0.55 |
| 26 | 1800 | 3691 | 626 | 215 | 56 | 57.78 | 0.54 |
| 27 | 192 | 669 | 2177 | 3304 | 46 | 51.72 | 0.37 |
| 28 | 2416 | 2197 | 1157 | 496 | 122 | 37.82 | 0.27 |
| 29 | 2903 | 92 | 1902 | 1424 | 67 | 22.29 | 0.30 |
| 30 | 2500 | 1781 | 1800 | 238 | 69 | 39.14 | 0.43 |

Number of candidates: 6388

## Comments on the analysis

### Difficulty

The difficulty index varies from about 10% in HL and 14% in SL (relatively ‘difficult’ questions) to about 92% in HL and 88% in SL (relatively ‘easy’ questions). The papers gave an adequate spread of marks while allowing all candidates to gain credit.

### Discrimination

All questions except HL Q37 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 number of blank responses throughout the test with a slight increase towards the end. This may indicate that some candidates had insufficient time to complete their responses, while others left the questions they were unsure of. 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 increasing the probability of selecting the correct response. If candidates concentrate on selecting the correct response – instead of working out the correct answer (as they might in paper 2) then there should be adequate time to complete all the questions and check the doubtful ones.

## 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, that is, those that illustrate a particular issue or drew comment on the G2's.

## SL and HL common questions

### SL Q3 and HL Q3

Gradient is in $ms^{-1}$ giving a speed, so A and B must be wrong. Most candidates went for C although it is the only one that does not have a non-zero initial velocity.

### SL Q4 and HL Q4

The area gives force times distance, that is, energy. This leads directly to C.

### SL Q12 and HL Q14

This was an unusual question, and it was disappointing that candidates did not naturally calculate 'average speed' as total distance divided by time taken.

### SL Q13 and HL Q15

Sinusoidal graphs are only generated in SHM when time is on the x-axis. Hence B and C are incorrect. D should be well-known to the candidates as the definition of SHM, but can be ruled out as it shows zero v when x = 0. Hence, by elimination, it must be A.

### SL Q17 and HL Q21

Power is inversely proportional to R when the potential difference is constant (as here) and proportional to R if the current is held constant. Many candidates were confused by this.

### SL Q18 and HL Q22

This was a fair question. It is not unusual to find that someone in a practical lesson will create this circuit and complain that their ammeter is not working! Yet about 70% of candidates opted for A or B, clearly expecting a reading on the ammeter. When teaching about ideal meters, the consequences of misconnecting them should be made clear.

### SL Q25 and HL Q35

Non-renewable fuels have been produced in the past and so can be produced again, so C represents a common misconception. The key to understanding what is meant by ‘non-renewable’ is consideration of the time scale of production and consumption.

### SL Q28 and HL Q36

The stem clearly states that the average temperature of the planet is constant, so neither B nor D can be correct. A correct understanding of albedo leads to A. The statistics would suggest that many candidates had not read the stem carefully.

## HL Questions

### Q2

When calculating uncertainties a distinction must be made between what is measured and what is calculated. The calculated should be made the subject of the formula before proceeding.

### Q9

As R is not defined in the stem it can be assumed it is irrelevant and therefore both C and D are incorrect. As we need to equate kinetic energy with potential energy to solve this problem, we can expect a factor of 2 from ½ $mv^2$. Hence B.

### Q18

70% of the candidates assumed the peak intensity does not change and opted for either A or B. But if the slit width is reduced then the energy transmitted (and hence peak intensity) will be reduced.

### Q19

The vast majority of candidates understood that the fractional change in the wavelength was needed and hence discounted B or D. But it would seem that they did not read the stem carefully, where it is clear that the wavelength has decreased – indicating that it is travelling towards Earth.

### Q20

It would seem that candidates had not read this question carefully and were trying to remember similar past questions. The incoming light is unpolarized, hence B and C must be incorrect. As the polarizer will reduce the intensity, A must also be incorrect.

### Q23

Same time….same acceleration……same (F/m). Hence it can only be D. Many candidates directly identified force with acceleration and chose A.

### Q25

This was the most difficult question in the paper for the candidates. Perhaps a simple sketch of a coil in a magnetic field would have helped them realise that there will be two occasions in the cycle when the power output is zero. Hence A and B (the most common options) must be incorrect. This is a $\sin^2$ curve and the average power will be just half the maximum.

### Q29

Candidates do not need to work through the algebra to generate the correct answer. They should know that the energy of a photon is inversely proportional to its wavelength (so A and B are incorrect) – and that it is the energies that need to add up. So D must also be incorrect.

### Q31

There was much discussion of this question on the G2's. Candidates are expected to choose the best answer and to discount factors that are negligible. The evidence would suggest that many candidates were randomly guessing the answer.

If the difference in the situations is that two isotopes of iron are used, then we can assume the charge is the same and that the distance and force remain unchanged. The slight difference in mass will not affect this.

### Q32

A is the only answer with the correct units. So the rest can be discounted.

### Q37

This was the only question that had a negative discrimination index, which means that the weaker candidates tended to prefer the correct response. As *e* is the emissivity of X and we are asked about the intensity of radiation leaving X, the correct response will be qualified by *e*. This automatically discounts A and C. The temperature of $T_2$ is clearly relevant as the box is emitting radiation towards X, which X will need to re-radiate. Hence it can only be D.

### Q38

Many candidates did not factor in *g*. Without it, though, the units would have been incorrect.

## SL Questions

### Q1

Consideration of units leads to C. It is not necessary to know the formula for the volume of a sphere.

### Q9

No formula is needed for this – just the understanding that the ratio required is equivalent to the ratio of the temperatures. This leads directly to the correct answer, B.

### Q14

There was a very even spread of responses to this question, albeit with a good discrimination index. We can only assume that the candidates did not read the question carefully as it is basic knowledge that a ray bends towards the normal when entering a denser medium. The slowing down of the wavespeed results in a reduction of wavelength as illustrated in B.

Candidates must be taught to illustrate wave behaviour with both wave diagrams and ray diagrams.

### Q16

This was a simple question yet a good number of candidates opted for A, showing perhaps that they had not read the question carefully (and were answering the question: In which arrangement is the resistance greatest?)

## Recommendations and guidance for the teaching of future candidates

Multiple Choice items are an excellent, 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 and 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. Candidates should be encouraged to develop strategies for spotting the correct answer – rather than working it out as they would in a paper 2. Among the strategies leading to successful completion of multiple choice questions are:

- Eliminate the clearly wrong responses.
- Consider the units. There is much evidence that candidates are not being taught the power and necessity of units. They are there to help the candidate not to burden them and will often lead to the identification of the correct response.
- If two responses are logically equivalent then they must both be wrong.
- Exaggerate a variable – this will often point the candidate in the correct direction, especially if a variable is in the denominator in one response and the numerator in another.
- Draw the situation while reading the stem. A simple sketch will aid in understanding the stem and often lead the candidate to the correct response. This is particularly important for those candidates with weak language skills.
- Distinguish between cos and sin functions – mentally making the angle $90^0$ will show which is correct.

- Use proportion: new quantity = old quantity x a fraction, where the fraction depends upon the variables that have changed.

- Notice the axes on graphs and use units to attach meaning to the gradient and the area.

- If all else fails, make an intelligent guess.

Candidates should make an attempt at every item. It should be emphasised that an incorrect response does not give rise to a mark deduction.

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 a skill shared by many candidates.

The stem should be read carefully. Inevitably some questions may appear at first sight similar to past questions, but candidates should not jump to conclusions. 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. 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. Teachers should be aware, that questions are constructed from the requirements of the syllabus – not from previous papers!

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.

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. Ample time should be apportioned to the teaching of such topics as Global Warming and the Greenhouse Effect in a rigorous fashion based upon physics. The common knowledge that most people have about these areas of the Guide is not always sufficient to answer questions on these topics, which are not trivial.

## Higher level paper two

### Component grade boundaries

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 11 | 12 - 23 | 24 - 34 | 35 - 43 | 44 - 53 | 54 - 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 - 16 | 17 - 21 | 22 - 26 | 27 - 31 | 32 - 50 |

# General comments

48 HL and 65 SL sets of G2 comments were received from centres. A high percentage of centres at both levels thought that the papers were appropriate in standard. 92% of HL teachers felt that the papers were of an appropriate standard (85% of SL teachers).

The clarity and presentation of the papers were regarded as good or satisfactory by the majority though the SL teachers were less happy with the clarity of wording. Almost 20% of SL teachers regarded the clarity of wording as fair or poor.

The majority of candidates demonstrated only a superficial knowledge of definitions. Examples in this paper were the unified atomic mass unit, radioactive half-life, latent heat of fusion and the electric resistance of a wire.

Many candidates failed to interpret the command terms in questions. For example on “show that” questions the candidate must clearly demonstrate how the information provided leads to the required result; “explain” questions require a logical discussion to be developed.

Calculations were generally done better than explanations.

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

- Drawing two worst fit lines through the extremes of error bars.
- Finding an uncertainty from worst fit lines.
- Stating the value and the uncertainty with appropriate precision.
- Outlining the conditions required for simple harmonic motion.
- Understanding the relationship between the direction of the force acting and the direction of the magnetic field for a moving charge.
- Outlining the difference between a polarized and an unpolarized wave.
- Explaining the Greenhouse Effect.
- Using the mass defect to calculate the energy absorbed during a nuclear reaction.
- Understanding that centripetal force is the resultant of the applied forces.

- Outlining how CCDs work.
- Calculating the final temperature when a heat exchange involves latent heat and specific heat transfers.
- Describing Einstein's photoelectric effect theory.

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

- Drawing a best-fit line which is a smooth curve.
- Knowing the shape of the line required for proportionality.
- Identifying acceleration and speed from the displacement-time graph for simple harmonic motion.
- Calculating forces in uniform electric and magnetic fields.
- Applying the Stefan-Boltzmann law.
- Drawing a radioactive decay curve.
- Applying knowledge of thermodynamic processes.
- Determining the activity of a radioactive sample given the half-life.
- Determining the equivalent resistance for a combination of series and parallel resistors.
- Determining the power dissipated in an electric circuit.

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

### Section A

### 1 [HL & SL] Data analysis question

ai) Most candidates could accurately read the absolute uncertainty from an error bar. The only mistake made was by those who wrote ± 2.

aii) Most were able to calculate the fractional uncertainties, but too often the figures were not compared.

aiii) This was mainly answered well, with few straight lines.

aiv) Most recognized the shape of the line required for proportionality.

bi) Few candidates appreciated the importance of using the best and worst fit lines in finding an uncertainty from the line of best-fit. Many candidates could not state the uncertainty and value to an appropriate precision.

bii) Most candidates successfully identified the unit.

## 2 [HL] & 4 Part 2 [SL] Mass on a spring

a) The conditions for simple harmonic motion were poorly outlined by most candidates. Few identified a relationship between force/acceleration and displacement, with most talking about it going backwards and forwards without slowing down.

b) This question was well answered by many. The only notable mistake was with reducing the time period of the damped oscillation.

ci) Identifying the peak of the graph with the resonant frequency was broadly successfully done but not many candidates stated that this occurs when the driving frequency is equal to the natural frequency.

cii) This sketch was generally well done.

## 2 [SL only] Tidal power station

ai) Many candidates provided a simple calculation with no explanation to show why the values were multiplied together. This did not provide sufficient evidence to show how the data provided lead to the given value.

aii) Few candidates realized that the energy produced by a water storage is dependent on half the height between the upper and lower water levels.

bi) Many candidates provided a general response such as “friction” without identifying the mechanism that caused the frictional losses.

bii) Few candidates could adequately explain the concept of degraded energy.

## 3 [HL & SL] Electric and magnetic fields

a) This calculation was successfully done by the majority of candidates.

bi) The magnitude of the magnetic field was often successfully calculated, but few candidates were able to identify the direction. Most thought that it was in the opposite direction to the electric field, presumably confusing it with magnetic force.

bii) Many thought that it would carry on in a straight line but this was often based on spurious reasoning.

## 4 [HL only] Sound

ai) Many candidates scored the first mark for the diagram showing the wavefronts closer on the side of the observer but most of the written explanations just repeated this and didn’t expand further.

aii) This question was very well answered with the majority of candidates choosing the appropriate formula and evaluating correctly.

bi) Most candidates were able to score full marks on this question.

bii) Again this was answered successfully.

ci) Few candidates included the words oscillations or vibrations in their answers and consequently scored zero marks.

cii) Many recognized that sound waves are longitudinal and that is why they cannot be polarized.

## 5 [HL only] Electromagnetic induction

a) This was generally very well answered with candidates recognizing how Lenz's Law relates to the situation. The point that was most commonly missed was the direction of the field caused by the induced current.

b) As with many of the calculation questions on this paper, this was very well answered.

## 6 Part 1 [HL] & 4 Part 1 [SL] Solar radiation and greenhouse effect

a) The Stefan-Boltzmann law was poorly understood with few candidates stating that the absolute temperature is raised to the fourth power.

b) This question was poorly done with few candidates substituting the surface area of the sun or the surface area of a sphere at the Earth's radius of orbit.

c) Despite not being able to state or manipulate the Stefan-Boltzmann law most candidates could substitute values into the expression and calculate a result.

d) This question was well answered at higher level.

e) To show the given value there is the requirement for an explanation of why the incident power absorbed by the Earth's surface is equal to the power radiated by the Earth, few candidates were successful in this aspect. Although most could substitute into the Stefan-Boltzmann equation they needed to either show that the fourth root was used or to find the temperature to more significant figures than the value given.

f) A surprising number of candidates could not explain the greenhouse effect. A common misunderstanding was that the Earth reflected radiation into the atmosphere and that the atmosphere reflected the radiation back to the Earth.

g) Many candidates did not name a greenhouse gas released in the burning of a fossil fuel and so did not adequately relate the increase in the average surface temperature of the Earth to the burning of fossil fuels.

## 6 Part 2 [HL only] Orbital motion

hi) Most were able to state gravitational force, however a significant number stated gravity and consequently did not get the mark.

hii) Many answers only discussed the astronauts and not the spaceship, missing points such as 'falling at the same rate' or 'with the same acceleration'.

i) This was well answered with candidates able to adequately show in their explanation where the expression comes from.

ji) Most appreciated that the effect of the force would be to decrease the total energy.

jii) Very few appreciated that they should use the equations above to answer this part of the question. As a consequence, the most common answer discussed a decrease in kinetic energy and a decrease in speed.

## 7 Part 1 [HL] & 5 Part 1 [SL] Nuclear reactions

ai) The definition of the unified atomic mass unit relates to the mass of the carbon 12 atom. Few candidates made this reference.

aii) Almost all were able to convert the mass unit into $MeVc^{-2}$.

b) Most could explain that new elements were produced but were not clear about how this was induced.

ci) This was well answered with the majority of candidates identifying the neutron.

cii) Few could relate the mass defect to the energy required to initiate the reaction.

ciii) Many were able to calculate the mass defect but did not realize that in this reaction it is the energy needed to initiate the reaction. This is why the products have more combined mass than the reactants.

di) The definition of radioactive half-life was often poorly done with few appreciating that half the radioactive nuclei decay into a more stable form. Those that explained that the activity of the sample would halve were more successful.

dii) Almost all were able to draw the decay curve.

diii) This was well answered with responses split between those that successfully found the number of half-lives elapsed in 2 hours and going on to find the activity of the sample and those that took the decay constant route. At SL, most successfully found the number of half lives elapsed in 2 hours and were able to find the corresponding activity of the sample.

## 7 Part 2 [HL only] Heat engine

ei) Most recognized the meaning of isothermal.

eii) The calculations were successfully done but some candidates missed a concluding statement.

f) This was well answered.

g) A significant number attempted a calculation based on the area under the graph on the previous page.

h) Many were able to relate this to the second law of thermodynamics and recognized that some of the thermal energy was given off to the surroundings.

## 5 Part 2 [SL only] Thermal energy transfer

ei) The majority related the latent heat to the energy required for a change of state but few successfully completed the definition by explaining that fusion is the change of state between a solid and liquid at constant temperature.

eii) This explanation was poorly done with few gaining full marks. Few could relate the change in potential energy during a change of state to fusion and vaporization.

fi) Of those candidates that established a relevant energy transfer equation, many did not include the heat gained by the ice once it had melted.

fii) Few could state two sources of energy loss that were not included in their energy equation.

## 8 Part 1 [HL] & 6 Part 1 [SL] Two children on a merry-go-round

a) Most were able to identify the relative speeds. The markscheme was amended to also include answers in terms of velocity.

bi) This was well-answered with most identifying a change in direction and a change in velocity.

bii) The majority were able to show the direction of the centripetal acceleration.

biii) Few identified a force that would act on Aibhe. They did not realize that the centripetal force is the resultant of the forces acting.

biv) Few realized from the diagram that it would be difficult provide an inward directed force on Aibhe’s upper torso. The consequence of this is that it would tend to continue to move in a direction which is tangential to the circle.

c) This was well done by many.

di) Many scored three marks here.

dii) Most candidates were able to gain both marks.

## 8 Part 2 [HL only] Charge-coupled devices (CCDs)

e) Many candidates recognized that that photons caused electrons to be given off but the answers then tended to jump straight to ‘causes a potential difference’.

fi) and fii) Many could do this calculation, but not necessarily in the steps given in the markscheme.

g) Few understood what was expected in this question.

## 9 Part 1 [HL] and 5 Part 2 [SL] Thermal Energy transfer

a) The majority related the latent heat to the energy required per kg for a change of state. Few successfully completed the definition by explaining that fusion is the change of state between a solid and liquid at constant temperature.

bi) Of those candidates that established a relevant energy transfer equation, many did not include the energy gained by the ice once it had melted.

bii) Many were able to identify two valid assumptions related to this experiment.

### 9 Part 2 [HL] and 6 Part 2 [SL] Electric circuits

c) [HL] & e) [SL] The definition of resistance was poorly attempted with many describing some difficulty that a current has in travelling down a wire.

f) [SL only] This calculation was generally well done although it was disappointing to see a significant proportion of candidates who did not know the formula for the area of a circle.

d) [HL] & g) [SL] Most were able to calculate the equivalent resistance of the combination of resistors and progress successfully to find the power supplied by the cell.

e) [HL] & h) [SL] Many recalculated the power but didn't provide an explanation and so consequently only scored one mark. Explanations were often detailed enough to score full marks.

### 9 Part 3 [HL only] Photoelectric effect and Heisenberg uncertainty principle

fi) Many wrote essentially the same point, about threshold frequency, in a number of different ways in their answers. Examiners were surprised at how few mentioned photons.

fii) It was common to score one mark here for discussing an increase in the photocurrent but a significant number scored two marks.

gi) This was answered well and of those that couldn't finish the calculation, most were able to calculate the kinetic energy for the first mark.

gii) The calculation in this question was tackled well by most.

## Recommendations and guidance for the teaching of future candidates

- Encourage candidates to set out calculations in a logical and presentable fashion.
- Encourage candidates to learn definitions as an aid to the understanding of concepts.
- Encourage candidates to go the extra step of calculating a final value to at least one more significant digit than the approximate one given in 'show that' calculations.
- Encourage candidates to learn the meanings of command terms.

## Higher level paper three

### Component grade boundaries

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 6 | 7 - 13 | 14 - 19 | 20 - 26 | 27 - 33 | 34 - 40 | 41 - 60 |

## General comments

The great majority of candidates were well prepared and showed that that they had sufficient time to complete the paper. The paper discriminated well and the level of difficulty for all of the options was comparable. There were many examples of good understanding in each of the options. Most candidates answered all questions from two options selected; very few candidates forgot to answer a part of a question from the options selected. Well prepared candidates answered two options, only some weaker candidates tried to answer selected questions from three options. The vast majority of candidates kept responses in the answer box provided and referred to the use of extension sheets in the answer box. However, there was a decline in the quality of handwriting. Many scripts were almost illegible and great deal of time and patience was required from the examining team to read and mark them.

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

All questions were accessible to candidates. However, many candidates failed in presenting their workings in logical and clear manner, explaining concepts in clarity and writing definitions of physical quantities. Some candidates showed that they do not follow the command terms and so do not answer the questions accurately (for example, define, show that, compare, distinguish).

Other difficulties:

- arithmetic and algebraic mistakes, calculator mistakes.
- showing working in “show that” questions, writing the ideas in words and not only in symbols and equations; it is recommended to show more significant digits than are given.
- layout of working in numerical questions.
- sequencing the presentation of facts to support an explanation and description.
- analysing real situations, where information is given in the form of sketch and/or graph, for example in questions 12 and 13.
- working with special units and converting to SI units, for example pc, MeV, ly, MeV $c^{-1}$.

Difficulties related to the specific parts of the syllabus:

- applying concept of pressure to the processes in the star (E 2.2).
- explaining Olbers’ paradox (E 4.2).
- power spectrum of amplitude modulated wave (F 1.5).
- communications with geostationary satellites (F 4.4).
- comparator (F 5.4).
- thin-film interference (G 6).

- relativistic kinematics (H 3).
- proper time intervals (H 3.2).
- total energy of accelerated protons (H 4.8).
- linear accelerators (J 2.3).
- total energy available from collision of particles (J 2.7).
- temperature of the Universe just after the Big Bang (J 6.1).

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

The best candidates have clearly seen the syllabus and show good understanding of its' content. The well prepared candidates can analyse the situations, present working in logical manner, and use proper terminology, physical quantities and units. The majority of candidates showed the ability to read and understand questions. They demonstrated understanding of facts and concepts and were able to use them with proper terminology. There was an improvement in the use of units and significant figures for this session.

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

### Option E – Astrophysics

This was a very popular option.

1 [HL] and 11 [SL] HL Candidates scored well. Some candidates did not refer to the Sun or other star. Only a few candidates outlined the nature of another body instead of comet, sometimes an asteroid. Some weaker answers mentioned a body just moving in space. At SL, many answers demonstrated a poor understanding of comets, ranging from parts of dead stars to asteroids to meteors and meteorites.

2 [HL] and 12 [SL] (a) There was evidence of superficial learning from the syllabus. Only a few of the best candidates wrote details of radiation and/or gravitational pressure, in response to the "outline" command term. There was evidence in (b) [HL only] that some candidates do not read the question carefully. Better candidates clearly outlined the processes before and after moving off the main sequence. Only a few demonstrated a good understanding of the term nucleosynthesis and answered this question clearly. These candidates referred to hydrogen to helium while in the main sequence and helium to carbon after leaving the main sequence. In (c) [HL], quite a high number of candidates outlined only the fate of a star with much greater mass and did not compare this with the fate of a star with mass equal to mass of the Sun. Candidates who understood that comparison is required, often omitted planetary nebulae. The main issue here was the superficial reading of the questions. Many responded with memorized tracts of stellar evolution and did not answer the question.

13 [SL] (a) was generally well-answered, although when the expected approximate answer is given it is important to determine the more exact answer for the final mark. It was excellent to see very few answers indicating 5lg – 51 x g. The most common mistake in (b) was not converting parsecs to

metres for the brightness/luminosity equation. In (c), most failed to explain why Sirius was more massive than the Sun using the HR diagram and referred to absolute magnitude without further explanation. Most could earn some marks in (d), but often failed to explain why d=1/p can be used (relating to 1AU).

3 [HL] and 13 [SL] (a) The vast majority of candidates correctly used the formula from the data booklet, correctly used the concept of absolute and apparent magnitude, presented their working and calculated the value more precisely than the value given in the question. Some candidates had difficulty in manipulating a logarithmic equation. (b) discriminated well. Many candidates used the equation from the data booklet value in non-SI unit and forgot to convert pc to meters. This was not a surprise to the examining team. Quite a high number forgot to square the distance. In (c), many candidates did not present their working in logical manner, especially those who did not understand mass-luminosity relations and incorrectly used the formula from data booklet. (d) discriminated well. There were a full range of answers from fully clear and logical to very weak. Many forgot to mention distant background stars, relative to which the angular change is measured. Practical exercises that involve the use of photographs from some astronomy textbooks could address this.

4 [HL only] Candidates generally understood the distribution of galaxies in the universe and could clearly explain red-shift.

5 [HL] and 14 [SL] This was poorly answered at both HL and SL. Candidates were not able to quantitatively explain this phenomenon. They did not derive the volume of the shell and did not use the inverse square law of luminosity. However, the majority of candidates presented that they know what Olbers' paradox is. The question also requires the ability to argue from a historical position, keeping track of which facts are appropriate.

## Option F – Communications

This option was not so popular, but many candidates scored well.

6 [HL] and 15 [SL] In (a) and (b), many candidates analysed the graph and identified that AM modulation has been applied. The values of frequencies and amplitude were read well. The majority of candidates worked with the correct units. In (c), only the stronger candidates demonstrated the ability to present the power spectrum of the modulated wave.

7 [HL] and 16 [SL] This was not difficult for candidates who understood the concept of digital sampling and analogue-to-digital conversion. Weaker candidates forgot to convert bytes to bits in (d), even if the conversion was written in the question stem.

8 [HL] and 17 [SL] Most HL candidates identified two types of satellites and suggested that a geostationary satellite is suitable for unbroken communication. Many SL candidates demonstrated an incorrect understanding of geostationary orbits as placing the satellite at rest relative to 'space' in (a) and (b). In (c), only the best candidates applied the concept of interference as a potential problem in two-way communication with a ground station.

9 [HL] and 7 [SL] This question appeared slightly more difficult to candidates. In (a) [HL only], only the stronger candidates stated that the resistance is infinitive or almost infinitive. In (b) and (c), candidates with little knowledge of this topic could not identify the saturation. In (d), only the stronger candidates identified that the circuit shown is a comparator. (d)(i) was accessible only for the strongest candidates, which were able to solve electric circuits (or at least potential divider) and also had sound knowledge of operational amplifiers.

## Option G – Electromagnetic waves

This was a relatively popular option.

10 [HL] and 18 [SL] This question was relatively well answered. In (a), the majority of candidates proved that they are able to use standard rays to find the position of the image, although too many candidates were not able to outline clearly enough whether the image is real. There were many correct answers to (b)(i), despite the general tendency for a lack of clarity in the answers to “define” questions. (b)(ii) and (iii) were well answered by the more able candidates. Generally the answers lacked clarity, explanation of formulas used and clarity of layout of working. More alternative solutions were accepted if clearly explained. Only a few construction based solutions was found, although this is by far the more understandable approach to the problem.

11 [HL] and 19 [SL] Too many candidates showed that they do not know the terminology and vaguely described other phenomena instead of dispersion, quite often scattering. Breaking into component colours was sometimes mentioned by the candidates but this was not accepted as correct as the question was about electromagnetic waves, not only about light. A reasonable number of correct answers were seen with reference of both different speed and index of refraction. In (b) only the stronger HL candidates clearly connected accelerated charge with the production of electromagnetic radiation. Most SL answers simply repeated the production of electromagnetic waves, missing the importance of the acceleration of the electron and not relating it to electric and magnetic fields.

12 [HL] and 20 [SL] This question discriminated very well and a full range was seen in the quality of answers. Well prepared candidates showed a good understanding and ability to apply the concept of interference. Lesser prepared candidates were not able to analyse the intensity-position graph. In (a)(i), candidates repeated the question without additional information and did not gain marks in (a)(ii) because they did not have enough information. (b) discriminated well between, as evidenced by candidates, those that analysed the situation and those that attempted to remember some information from problems with similar context. Well prepared HL candidates realized that point P has no special position on the line M. (b) was very poorly answered at SL. The explanation of why the intensity is always zero was generally unclear and did not signify thought.

13 [HL only] This part of syllabus does not appear to be well understood. Some candidates calculated the wavelength but many used the formula from the data booklet without explanation. Only a few analysed the situation well. Even the well prepared candidates had a problem with the radian angle unit. The majority of candidates found the change in shape of one of the plates very difficult. Only a few candidates realized that the number of fringes must not change.

14 [HL only] This question was generally well answered. The majority correctly read the value of minimal wavelength from graph and used the correct equation (written also in data booklet). The majority of answers to (b) were standard and correct, with more mention of voltage than temperature. In (c), many answers achieved two marks.

## Option H – Relativity

This was a very popular option.

15 [HL] and 8 [SL] There were a large variety of answers to (a). Many candidates stated that the frame of reference is not accelerated. Many candidates did not explain the term “frame of reference” in terms of a “co-ordinate system”. It was a rare answer that earned more than one mark. In (b)(i), the majority of candidates properly calculated the time. Some wrote the incorrect unit (ly) instead of y or s.

There is room for improvement in responses to (b)(ii). The vast majority of candidates used the formula for time dilation. They did not notice that it is not normal for the observer on the spaceship to know the time measured on the space station. The correct calculation, length and speed measured, appeared only very rarely. There was a good variety of answers to (c). Many candidates still do not know the term proper time interval, clearly defined in relativity. Many incorrectly referred to both events occurring in one frame of reference rather than one point in space in their answer. Most did attempt a reason. In (d) many candidates proved that they understood the concept of simultaneity. However, many did not respond to the command term “discuss”. Many candidates were confused between object (in a specific frame of reference) and event.

16 [HL only] The units of potential difference were incorrectly stated as GeV in this question. The markscheme was adjusted to ensure no candidate was disadvantaged and all examiners were asked to identify any candidates who appeared to have been thrown by the error. On the whole, candidates had interpreted the question with the correct unit of GV.

Correct answers were given by those who worked in logical manner and who clearly stated that total energy of the proton is the sum of kinetic energy and rest mass energy. The derivation of momentum from the formula was not easy for candidates. Candidates with basic arithmetic and algebra failed here. The more able candidates found the momentum in a clear, straightforward way. Looking through the formulas in data-booklet without understanding is not appropriate here. Many candidates confused kinetic energy with total energy.

17 [HL only] This relatively standard question was generally well answered. Some candidates lost some marks in (b), if they did not read the question carefully. General statements about this experiment often did not score, if the answer was not focused to the question – how they used the apparatus. Many failed to mention the need to rotate the apparatus and compare the interference patterns.

18 [HL only] The principle of equivalence is generally well understood by the candidates. However, the majority of candidates wrote general statements (not wrong) but not in a sufficiently clear sequence. There were many vague statements about gravity and inertia in (a), which was not in response to the question of “state the principle...”. In (b)(ii), some candidates did not realize that the question remained focused on the principle of equivalence. Good answers to this question required a deep understanding of the principle.

19 [HL only] Many well prepared candidates realized that the light is bent. However, “outline” requires a brief account or summary, so a more detailed answer was required here. Information such as the galaxy has very large mass should be mentioned, at least implicitly.

## Option I – Medical physics

This was quite a popular option.

20 Surprisingly, too many candidates do not know the range of audible frequencies. Many stated an interval similar to the frequency range for normal communication and others stated values in MHz. However, the more able candidates had no issue with the correct range. In (b), candidates demonstrated a good knowledge of the quantities used in the description of sound. Some candidates gave superficial answers; some described intensity as “energy” not “power”; others forgot to mention “per unit area”. (c) was well answered by the more able candidates. However, it was rare to find an answer that mentioned the assumption that all noise was split only into two ranges without overlap.

(d) was well answered. The majority realized that there were two marks for the question and so tried to describe more than one effect on hearing.

21 Candidates do not use precise enough wording in definitions, as seen in answers to (a). Many candidates do not differentiate between attenuation coefficient and half-value thickness. In (b), the majority of candidates had no problem with the determination of attenuation coefficient from the graph and used it in the calculation of the result. In (c), many candidates did not mention the light emitted from the intensifying screen and that the film used for X-rays is also sensitive to light.

22 (a) many candidates forgot to mention “per unit mass” in the description of absorbed dose. In (b) it was important to divide the absorbed energy by the mass to calculate the absorbed dose. Other candidates answered well, with clear and well laid out answers. In (c), the majority of candidates proved that they understand the differences between physical, biological and effective half-lives, but often there was a lack of clarity in (c)(i). In (c)(iii), a reasonable number of candidates realized that the physical half life of isotope X is too small for cancer treatment, or even for distribution from the production company to the hospital.

## Option J – Particle physics

This is not a very popular option, well answered only by very well prepared candidates.

23 [HL] and 9 [SL] There were a good variety of answers to this question. The stronger candidates identified particles in the Feynman diagram in (a) and (b). At SL, in (b)(i) and (ii), many did not answer the question that was asked. In (c), many candidates realized that the strangeness is not conserved in weak interaction. Too many candidates forgot to mention the interaction C.

24 [HL] and 10 [SL] This was generally well answered at HL. Some candidates tried to use any formula from the data booklet. These same candidates struggled with (b), where it was difficult to find an acceptable answer without sufficient knowledge of the topic. Very few candidates mentioned that a single quark cannot be separated, cannot be observed. At SL, the answers to (a)(i) were very badly worded and often involved descriptions of transfers of energy. (a)(ii) was very poorly answered with few realizing how to deal with the mass given but rather turning to the Data Booklet equation. (b) was poorly explained.

25 Surprisingly too many candidates struggled with (a). These candidates proved that they cannot apply basic knowledge of electrostatics in situations such as these. (b) was slightly better answered. Some candidates which struggled with (a) were able to outline the acceleration of protons in a logical manner. (c) was the most difficult part of whole paper and only small number of candidates were able to present well directed working and reach proper values. There was much confusion in the answers and it appeared that candidates were not well prepared for such a multi-step problem. A link between basic mechanics and particle physics should be fostered.

26 This was generally well answered by well prepared candidates. Many identified the Z boson in (a)(i). In (b), incorrect answers were rare. Candidates with sound knowledge answered well and others did not answer at all. Almost all candidates achieved at least one mark for (c).

27 This question was well answered only by candidates with sufficient knowledge on the temperature of the universe just after the Big Bang, and with deep understanding of electron-positron pair production.

## Recommendations and guidance for the teaching of future candidates

It is recommended that candidates:

- are informed about aims, objectives and syllabus details at early stage of study.
- are informed about standard command terms and that these terms are often used in communication between teacher and candidate during the learning/teaching process. This seems to be equally important in teaching candidates who are working in their first or second language.
- study both options before the revision of core physics, so that they can see connections between topics.
- use the Data Booklet when solving multistep, complex problems.
- practice past papers.
- try not only understand and apply, but also remember (precise) formulations of definitions, especially of physical quantities used only in the options.
- try to connect the knowledge of the options to core physics, to put into context the use of general physics quantities as energy, power, force, pressure etc.
- study options in lessons, in group of candidates and with the teacher.
- are trained to express their ideas in written form, in a logical manner, in a proper layout, showing each step, even if "fully clear". Sometimes candidates do not write such obvious information, such as that mass has gravity, or the speed of light is constant, and it is sometimes hard to see if such information is or is not implicit in their answers. If such information is necessary, especially in "show that" questions, it should be mentioned. For the majority of candidates, it is sometimes easier and better to answer in a form of list of arguments rather than in a form of short essay.
- are encouraged to write some words explaining their working also in calculations, derivations and other use of formulas. In not fully correct answers or alternative answers this can be helpful and candidates can reach some marks for partially correct working. Also it helps candidates can find their own mistakes in derivation, or calculation and can correct their answer.
- are not to neglect units. Sporadically we can see mistakes such as well calculated distance and time unit used, or well calculated energy and unit of power used.
- are trained to use units such as MeV, ly, MeV $c^{-1}$ and also are focused to converting the units to SI units where appropriate.
- are encouraged to be careful with the difference between "is equal" and "is proportional".
- are performing the full range of empirical learning as in core physics; activities as simple lab demonstration of parallax, location of a star in the night sky, or working with an interactive

model of X-ray tube. Activities such as these can significantly raise the self-confidence of the candidates in optional topics.

Candidates must be reminded that every word must be readable. The examiners must be able to read and assess the answer. Answers must be only in the boxes and on additional sheets.

Candidates should also be reminded that incorrect answers are not penalized. The working and the answer should be crossed out only if an alternative better answer is given. Sometimes a partially correct answer is crossed out and no other answer is offered.

## Standard level paper three

### Component grade boundaries

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mark range: | 0 - 4 | 5 - 8 | 9 - 12 | 13 - 16 | 17 - 21 | 22 - 25 | 26 - 40 |

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

- Differentiation between command terms such as define, state, explain, deduce, outline.
- Conversion of units.
- Recall of definitions (usually descriptions were given).
- Rayleigh's criterion of resolution of two point sources.
- Effects of change of angle on diffraction.
- Fundamental and higher modes of resonance of closed pipes.
- Doppler effect in a more general situation.
- De Broglie's hypothesis.
- Explanation using Heisenberg's Uncertainty Principle.
- Definition of decay constant.
- Relationship between number of decayed nuclei and daughter nuclei.
- Retrieval of the image stored in a charge-coupled device (CCD).
- Interference of light to recover information stored on optical disc.
- Recognition of comparator.
- Calculation of the resistance for a comparator.

- Characteristics of an inertial frame of reference.
- Identification and justification of proper time interval.
- Principle of simultaneity.
- Fundamental interactions between elementary particles.
- Definition of exchange particle.
- Quark confinement.
- Explanation of stability of a star.
- Varying units for different equations e.g. pc or m, eV or V.
- Use of HR diagram to explain the relation between the temperature and mass of a star.
- Newton’s model and Olber’s paradox.
- Sketch of power spectrum of a modulated wave.
- Polar orbiting and Geo-stationary satellites.
- Definition of dispersion of light.
- Production of Electromagnetic waves by an oscillating charge.
- Destructive interference.

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

- In general, the working for calculations was generally well presented and given in the detail required. The numerical answers had units accompanying.
- Calculation of angle for minimum diffraction.
- Sketch graph of variation of intensity curve for different angles of diffraction.
- Calculation of frequency of source as measured by an observer (Doppler’s effect).
- Calculation of wavelength, momentum and energy using de Broglie.
- Determination of the distance of closest approach using Rutherford’s scattering experiment.
- Determination of the distance of a star using apparent and absolute magnitudes.
- Determination of the luminosity of a star.
- Determination of the distance of a star using parallax angle method.

- Modulation of signal and carrier wave.
- Ray tracing to locate the image formation in a compound microscope.
- Calculation of total linear magnification of compound microscope.

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

### Option A – Sight and wave phenomena

1 (a)(i) The main error was to forget to multiply by 1.22. (a)(ii) was mostly well done. The most common error was to misplace the minima which should be at 0.40 rad. (b) Many did not shift the maximum from (a)(ii) in by 0.25 rad in either direction horizontally. In (c)(i) most could give some minimal definition of Rayleigh's criterion of two point sources. The most common error was to identify the equation. Most answers to (c)(ii) did not involve quantitative answers using the values in the previous questions. However, reasons were generally attempted even if the reason was spurious.

2 (a)(i) Many attempted to use the relationships of an open pipe, then "fiddled" to make the number match the expected (given) value rather than the closed pipe of the question. The question required that the workings be shown clearly. Those who used the length of the pipe from the previous question scored well in (a)(ii). There was a significant number describing the Doppler Effect as a consequence of position rather than relative motion in (b)(i). That the frequency is observed or perceived as different was often forgotten. Most used the equation in (b)(ii) well, although some substituted the speed of light for a sound question.

3 Often only one or two matching differences between photopic and scotopic vision were given. Candidates are encouraged to answer clearly, for example in a table, to show the match of cones/rods, colour/no colour and bright/dim light. Many seemed to view detecting motion as the match to detecting colour, which is incorrect.

### Option B – Quantum physics and nuclear physics

4 Answers to (a) frequently indicated some knowledge but rarely earned both marks. The most common mistake was to refer to light particles and waves. (b)(i) was not well answered. Many succumbed to mistakes in calculations. (b)(ii) was well answered and (b)(iii) was usually well answered. Most missed the easier calculation using momentum from (b)(i) rather than wavelength from (b)(ii). Many claimed one mark for 'Heisenberg's Uncertainty principle' or the equation in (c), but very few could explain why a precise knowledge of momentum precluded a method of determining position. Usually it was expressed as 'if you know one you can't know the other' in some form or another. (d) was not well answered, with many referring to the amplitude indicating the amount of energy in the wave or the amplitude determining the position of an electron.

5 (a) was very poorly answered. In (b)(ii), many candidates did not recognize that the number of polonium nuclei produced is equal to the number of radon nuclei decayed, and instead used the residual number of radon nuclei as the polonium number. Many wasted time converting both values in moles to number of nuclei. Many didn't recognize that in (c), at distance of closest approach kinetic energy lost equals electric potential energy gained. This question was very poorly answered.

### Option C – Digital technology

6 (a) was not very well answered by the majority of candidates. (b)(i) and (ii) was either well answered or (more commonly) poorly answered. Many may have succeeded if they had set out their thinking more clearly, so they could see what they were doing. Most did not answer the question that was asked in (c), which was about the pit/land interference. Rarely was the refractive index used correctly in (d), and it was often ignored completely. A quarter wavelength was well-understood.

7 A minority of answers were correct for (a). In (b), the graph rarely showed the saturation regime and often did not carry the errors made in (a). (c)(i) was very rarely correctly answered and (c)(ii) was very poorly answered.

## Recommendations and guidance for the teaching of future candidates

Candidates need to practice interpreting a question to decide what is required. This can be achieved by issuing questions that do not need to be answered, but only need to be used to determine what is required. Once that is determined, then they could answer the question, as a separate exercise. Very few papers showed any evidence of analysis of the question, by highlighting or underlining significant command terms e.g. show, deduce, calculate, explain.

Be aware of the quality of the hand-writing to enable the examiner to be able to read it. The aim needs to be to communicate clearly, so diagrams can often be helpful.

Definitions are at the very heart of Physics – they must be known and practiced.

If the question gives the expected value, the working should show at least one more significant figure than the given answer, to present evidence of a correct calculation. For example, 13(b) where 2.6 was expected, so the answer needed to be 2.64.

Questions requiring show or deduce should clearly show the steps involved, with the number of marks for the question being a hint at the number of steps.

Candidates need to practice using Physics language correctly. Words such as interference, energy, field, velocity, mass, weight, gravity are have specific meanings and should not be misused.

Candidates need to be familiar with the Data Booklet, with the units used in each formula, and the proper use of each.

When asked to compare two quantities or situations, e.g. question 3, a simple way of comparison is to have two columns where the ‘matched’ terms can be shown. It is faster than writing sentences and usually clearer.

## Further comments

Work that is crossed out is not marked, even if it can be seen to be correct.