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# Physics

*Timezone 2*

*To protect the integrity of the assessments, increasing use is being made of examination variants. By using variants of the same examination, students in one part of the world will not always be responding to the same examination content as students in other parts of the world. A rigorous process is applied to ensure that the content across all variants is comparable in terms of difficulty and syllabus coverage. In addition, measures are taken during the standardisation and grade awarding processes to ensure that the final grade awarded to students is comparable.*

# Contents

# Grade boundaries

## Higher level overall

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-13 | 14-24 | 25-35 | 36-45 | 46-57 | 58-67 | 68-100 |

## Standard level overall

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-10 | 11-18 | 19-29 | 30-39 | 40-50 | 51-60 | 61-100 |

## Internal assessment

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-3 | 4-6 | 7-10 | 11-13 | 14-16 | 17-19 | 20-24 |

## Higher level Paper one a

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-9 | 10-14 | 15-17 | 18-20 | 21-24 | 25-27 | 28-40 |

## Standard level Paper one a

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-5 | 6-7 | 8-8 | 9-10 | 11-12 | 13-14 | 15-25 |

## Higher level Paper one b

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-2 | 3-4 | 5-6 | 7-8 | 9-11 | 12-13 | 14-20 |

## Standard level Paper one b

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-2 | 3-4 | 5-6 | 7-8 | 9-11 | 12-13 | 14-20 |

## Higher level Paper two

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-8 | 9-16 | 17-26 | 27-36 | 37-46 | 47-56 | 57-90 |

## Standard level Paper two

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0-2 | 3-5 | 6-11 | 12-16 | 17-21 | 22-26 | 27-50 |

# Internal assessment

## The range and suitability of the work submitted

The first exam session with the new curriculum went well. The new IA criteria have been simplified with fewer criteria and fewer strands per criterion. Many schools followed the requirement of a word count (text words only), and the student alpha-numeric ID listed at the top of reports. Although there was a wide range of work submitted, well-known investigations appeared numerous times. The most popular investigations included: viscosity of a liquid and temperature, period and length of a pendulum, coefficient of restitution of a bouncing ball, graphite and resistivity of a pencil, mixing problems with a concentration of a solution and its specific heat capacity, frequency and string tension (sonometer), refractive index of water and temperature, the resonating wineglass (A. P. French article from1983), Hooke's law, spring constant and temperature, projectile motion. Many of these referenced the same resources (previous IAs found online). Examples of simplistic study investigated included: how the resistance of wire varied with length, how voltage affects current, and another how wavelength relates to frequency for sound waves. On the advanced side, several students attempted to determine the permeability of free space (but not in free space); Several imaginative investigations included determining the maximum power output from a battery (where the internal resistance equaled the external load), damping pendulums (advanced mathematics), the varying tensions in a pendulum string, and measuring an unknown mass without using a scale. Even the simplest research questions were able to earn marks when the student demonstrated a depth of understanding and the relevant skills that were required. Only ill-defined investigations had trouble achieving satisfactory marks, where there were two independent variables. Some of the more advanced topics demanded too much from students, and often obvious issues were not addressed.

## Student performance against each criterion

### Research Design

The initial stage of any investigation is the most important. Students must articulate a well-defined research question, identifying appropriate quantifiable variables and describing a method that can address the research question properly. This means that an appropriate range of data with appropriate precision can be obtained. If, for example, a student wants to measure how the refractive index of water changes with temperature, then their method must be able to discern the third decimal place in the refractive index. Background information needs to be focused on the physics relating to the research question (not general topic background or history of physics). If investigating refractive index and the temperature of water, students need to only state Snell's law and identify the quantities. Some students took several pages deriving the equation, an equation that can be found in the Data Booklet. They only speculated, without reason or evidence, how temperature would affect the refractive index. A little research on the research question itself would have improved the study. If the research question is a restatement of a well-known phenomenon, then it should be stated in another way, perhaps suggesting a confirmation of the known theory. The relationship between the tension in a guitar string and frequency is standard textbook knowledge, as is the range of a projectile and angle of launch. Students should use this knowledge to guide their investigation and not pretend to not know the relationship. The expectation of a research question and the statement of the conclusion should be quantified. Concluding that "as the tension of a guitar string increases, so does the frequency" is not an adequate conclusion for physics. If, for example, the student investigates the relationship between a guitar string tension and frequency, given the know equations, there is no need to write a hypothesis. They are confirming the known function. Finally, some reports include a personal engagement section. This attention is no longer needed and tends to detract from the overall quality of the report.

## Data Analysis

Analysis under the new curriculum assessment criterion repeats many of the well-known and established tools and skills. Assessment under Data Analysis was often high as students demonstrated competent and focused analysis techniques. Some of the common mistakes included claims of inconsistent significant and meaningless significant figures (such as an uncertainty of 12.363352%), confusing the terms proportional and linear, terms of speed and velocity, range and distance, confusing a linear graph line with a negative gradient with an inversely proportional function, using only the first and last data point uncertainty bars to establish minimum and maximum gradients, using statistical analysis of data while ignoring much larger uncertainties based on experimental precision. A common fault is seen with the approach of forcing a linear line on data scatter that is not linear. Occasionally students would fill several pages with simple calculations, such as averaging repeated measurements to find the mean. Such calculations can be done on a spreadsheet, and then the student can appreciate precision, significant figures and uncertainties. Students should realize: (1) No calculation can improve precision. The result of addition and/or subtraction should be rounded off so that it has the same number of decimal places (to the right of the decimal point) as the quantity in the calculation having the least number of decimal places; a sum or difference is not more precise than the least precise number. (2) Significant figures in the result of multiplication and/or division should be rounded off so that the answer has as many significant figures as the least precise quantity used in the calculation; a product or quotient has no more significant digits than the number with the least number of significant digits.

## Conclusion

Under Conclusion students nicely described their analysis as it related to the research question. However, simply describing in words about the numbers in a graph does not focus on the issue. Repeating the procedures and steps of what was done in the investigation also does not focus on the issue of answering the research question. Focus under the conclusion criterion needs to be about physics (not the statistical meaning of the data). A well-defined research question will help the student address the conclusion assessment expectations. Another weakness of some students was the second strand under Conclusion. Failure to address this reduces a best-fit assessment. Here, the student needs to justify their conclusion through relevant comparison. That is, does their result align with the known world of physics? Often a reliable source can be used to compare with. If measuring gravity in the Philippines, the accepted value is not 9.81 but is 9.7844. Research can confirm this. If there is no accepted standard, then a plausible value or range would be acceptable. For example, the spring constant for an unknown spring can be compared to known values of similar springs.

## Evaluation

As in the legacy assessment criteria, evaluation proves the most difficult criterion to address. Students are well versed in the standard textbook list of random, systematic and human errors, but often failed to connect these to their actual analysis and methodology. It is not easy to recognize what aspects of a procedure produce which errors and uncertainties. All investigations are limited to scope and precision of data; no experiment ever ‘proves’ a result. If the data graphed reveals a trend, the student could consider extrapolating the trend to higher and lower ranges and see if there is a meaningful interpretation. Does the systematic shift have a physical meaning (e.g. internal resistance) or a procedural problem (e.g. delay in timing)? The second strand in the evaluation criterion asks for realistic and relevant improvements to the issues identified in the first strand. Often students fail to appreciate the subtleties of an appropriate evaluation, and simply state textbook improvements like using a video camera or repeating more measurements. Occasionally a student would earn top marks under Evaluation by identifying a single major weakness and explaining an appropriate improvement. Insight here is more important than a long list of generic issues and vague improvements. Conclusion and Evaluation are clearly linked, and one-half of the total marks for the IA are given to these two criteria. What the investigation establishes is then as important as what is studied and how it is studied. Some students are listing 'strengths' of their investigation along with weaknesses under their evaluation comments. Strengths are neither relevant nor required for assessment under evaluation. It is better to focus on the limitations of the method and analysis.

## Recommendations and guidance for the teaching of future students

- When writing reports, students should focus on the individual descriptors of each strand, not just the overall criterion statement.
- Be aware of inconsistent significant figures and unrealistic precision.
- When repeated measurements do not vary, the minimum uncertainty is the least count (not zero).
- Do not derive well-known equations that are covered in textbooks. Simply describe what they mean and how they will be used.
- Do not force a linear fit on a graph unless justified. Theory can suggest an appropriate linear function, or sometimes dimensional analysis can. Residuals can be used to justify or reject a suspected linear function. Students must not assume a linear fit without justification.
- Do not use the extremes of the first and last data points for determining minimum and maximum gradient range. In several cases, students claimed both positive and negative gradients, thus making a conclusion meaningless.
- Rejecting a datum as an outlier requires justifications (not that the results simply look better).
- Make sure word count and ID are on the first page, and that the investigation has a descriptive title, and page numbers.
- Teachers and students must be aware of the IB guidelines on the use of artificial intelligence. An evaluation for an investigation or even the background produced by AI content is not authoritative.

## Further comments

- Given the new word limit, many students are producing reports ranging from 25 to 43 pages and claiming 3000 words. In the legacy curriculum, reports were noticeably shorter, more concise and more focused. Students should not think that more is better.
- The majority of teachers marking was fair, consistent and appropriate. Detailed comments help examiners in justifying marks. However, simply restating the descriptors does not help examiners.
- Demonstration of competence and understanding of the tools and skills of assessment is the key to a successful investigation. Clever or contrived research questions often get muddled and fail to address all the assessment expectations. However, students are encouraged to follow their passion and often find that advanced topics (topics normally found at university level) can result in a successful investigation.

# Paper one a

## General comments

There were 22 questions which were common to the SL and HL papers, 3 questions only on SL and 18 only on HL.

### SL

Over 80% of teachers who provided feedback regarded the level of difficulty of the paper to be appropriate and under 20% judged it too difficult. About 85% said that the paper was of a similar standard or a little more difficult than last year.

### HL

Some teachers expressed the opinion that there were too many ratio questions on the paper.

Questions of this type are an important component of multiple-choice papers and teachers should ensure that their students have plenty of opportunities to practise them.

The question key accepted answer is indicated by a shaded cell.

Higher Level

**International Baccalaureate**

Multiple Choice Analysis Report

**PHYSICS HL PAPER 1 (MCQ) Timezone 2 MAY 2025 in Question order**

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 1 | 1042 | **3667** | 937 | 1398 | 59 | 51.63 | 0.32 |
| 2 | 996 | 2405 | **3437** | 219 | 46 | 48.39 | 0.43 |
| 3 | 1871 | 1769 | 578 | **2873** | 12 | 40.45 | 0.28 |
| 4 | 993 | 82 | 4323 | **1694** | 11 | 23.85 | 0.27 |
| 5 | 3204 | 686 | 1146 | **2036** | 31 | 28.66 | 0.40 |
| 6 | **4160** | 2069 | 394 | 447 | 33 | 58.57 | 0.57 |
| 7 | 1190 | 386 | 1541 | **3976** | 10 | 55.98 | 0.52 |
| 8 | 816 | 423 | **4451** | 1375 | 38 | 62.66 | 0.36 |
| 9 | 1443 | 1040 | **4090** | 475 | 55 | 57.58 | 0.48 |
| 10 | 1114 | 2158 | **2596** | 1190 | 45 | 36.55 | 0.18 |
| 11 | 431 | 743 | **3262** | 2658 | 9 | 45.92 | 0.29 |
| 12 | 1242 | 1316 | 1220 | **3310** | 15 | 46.60 | 0.34 |
| 13 | 634 | 1104 | **4615** | 709 | 41 | 64.97 | 0.57 |
| 14 | 1505 | 1204 | 2472 | **1881** | 41 | 26.48 | 0.34 |
| 15 | 678 | 1021 | 498 | **4896** | 10 | 68.93 | 0.48 |
| 16 | 394 | **1790** | 1546 | 3347 | 26 | 25.20 | 0.31 |
| 17 | 446 | **2582** | 781 | 3276 | 18 | 36.35 | 0.33 |
| 18 | **3534** | 870 | 1945 | 746 | 8 | 49.75 | 0.53 |
| 19 | **4654** | 1172 | 691 | 552 | 34 | 65.52 | 0.50 |
| 20 | 894 | **2605** | 1421 | 2146 | 37 | 36.67 | 0.33 |
| 21 | **4848** | 897 | 1068 | 247 | 43 | 68.25 | 0.42 |
| 22 | 1971 | **2801** | 1277 | 1017 | 37 | 39.43 | 0.38 |
| 23 | 37 | 81 | **6460** | 520 | 5 | 90.95 | 0.13 |
| 24 | 2473 | **3459** | 621 | 474 | 76 | 48.70 | 0.43 |
| 25 | **5284** | 187 | 1313 | 305 | 14 | 74.39 | 0.37 |
| 26 | **2937** | 2955 | 675 | 496 | 40 | 41.35 | 0.16 |
| 27 | **3676** | 1164 | 1524 | 698 | 41 | 51.75 | 0.53 |
| 28 | 741 | **2139** | 3387 | 768 | 68 | 30.11 | 0.19 |
| 29 | **3742** | 1229 | 1558 | 532 | 42 | 52.68 | 0.42 |
| 30 | 374 | 574 | 1036 | **5089** | 30 | 71.65 | 0.18 |
| 31 | **5690** | 281 | 366 | 734 | 32 | 80.11 | 0.26 |
| 32 | 1080 | 227 | 195 | **5586** | 15 | 78.64 | 0.43 |
| 33 | 1240 | 2483 | **2329** | 987 | 64 | 32.79 | 0.12 |
| 34 | 1265 | **4626** | 468 | 701 | 43 | 65.13 | 0.49 |
| 35 | 707 | **2710** | 2501 | 1099 | 86 | 38.15 | 0.26 |
| 36 | 2210 | 972 | **3388** | 449 | 84 | 47.70 | 0.53 |
| 37 | **4464** | 593 | 1063 | 940 | 43 | 62.85 | 0.40 |
| 38 | 893 | 1335 | **4096** | 671 | 108 | 57.67 | 0.54 |
| 39 | 215 | 397 | 1505 | **4944** | 42 | 69.60 | 0.45 |
| 40 | 1101 | **4306** | 740 | 890 | 66 | 60.62 | 0.49 |

**Number of candidates : 7103**

Standard Level

**International Baccalaureate**

Multiple Choice Analysis Report

**PHYSICS SL PAPER 1 (MCQ) Timezone 2 MAY 2025 in Question order**

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 1 | 918 | 1939 | 705 | 893 | 39 | 43.15 | 0.34 |
| 2 | 830 | 1916 | 1570 | 158 | 20 | 34.94 | 0.40 |
| 3 | 1513 | 1152 | 466 | 1352 | 11 | 30.08 | 0.25 |
| 4 | 818 | 159 | 2645 | 864 | 8 | 19.23 | 0.14 |
| 5 | 2089 | 479 | 1155 | 755 | 16 | 16.80 | 0.17 |
| 6 | 1058 | 878 | 2112 | 401 | 45 | 47.00 | 0.41 |
| 7 | 558 | 1682 | 1506 | 718 | 30 | 33.51 | 0.12 |
| 8 | 267 | 667 | 1870 | 1676 | 14 | 41.61 | 0.27 |
| 9 | 693 | 960 | 2068 | 741 | 32 | 46.02 | 0.59 |
| 10 | 1201 | 892 | 1504 | 867 | 30 | 19.29 | 0.24 |
| 11 | 1088 | 354 | 1887 | 1141 | 24 | 41.99 | 0.34 |
| 12 | 363 | 1193 | 659 | 2258 | 21 | 26.55 | 0.15 |
| 13 | 1471 | 548 | 1610 | 852 | 13 | 32.73 | 0.46 |
| 14 | 728 | 2251 | 1083 | 397 | 35 | 50.09 | 0.52 |
| 15 | 823 | 1323 | 1025 | 1298 | 25 | 29.44 | 0.21 |
| 16 | 2972 | 447 | 516 | 543 | 16 | 66.13 | 0.36 |
| 17 | 968 | 1488 | 1235 | 775 | 28 | 33.11 | 0.21 |
| 18 | 1801 | 1734 | 559 | 370 | 30 | 40.08 | 0.26 |
| 19 | 1579 | 803 | 1395 | 687 | 30 | 35.14 | 0.42 |
| 20 | 3073 | 322 | 311 | 758 | 30 | 68.38 | 0.37 |
| 21 | 957 | 209 | 220 | 3087 | 21 | 68.69 | 0.49 |
| 22 | 1833 | 816 | 1535 | 253 | 57 | 34.16 | 0.44 |
| 23 | 2480 | 536 | 835 | 617 | 26 | 55.18 | 0.44 |
| 24 | 196 | 331 | 1034 | 2905 | 28 | 64.64 | 0.48 |
| 25 | 813 | 2118 | 679 | 785 | 99 | 47.13 | 0.49 |

**Number of candidates : 4494**

Comments on the analysis

## Difficulty

The difficulty index, or facility index, measures the percentage of students who answered a question correctly. A higher index means an easier question.

## Discrimination

The discrimination index measures how effectively a question distinguishes between students of differing abilities. Generally, a higher discrimination index indicates that a greater proportion of higher-performing students selected the correct answer compared to lower-performing students. However, a low discrimination index does not necessarily imply that a question is flawed. It may reflect a widespread misconception among students or be associated with questions that are either very easy or very difficult.

## Calculator use

Since students are now permitted to use calculators, several multiple-choice questions in this paper did require their use.

## ‘Blank’ response

Blank responses were more prevalent towards the end of the paper at both levels. Students should be reminded that there is no penalty for incorrect answers and so if the correct response is not known then an educated guess should be made. Often some of the distractors can be easily eliminated so increasing the chance of selecting the correct response.

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

### SL2/HL2

This question was answered correctly by over 48% of HL students and almost 35% of SL students. In HL more gave the correct answer C than the most frequent incorrect answer B but in SL the incorrect response B was most frequent, possibly due to students ignoring the acceleration and giving the displacement over the first two seconds.

### SL4/HL4

A clear majority of students gave incorrect answer C, probably missing the fact that the car is travelling in a circular path and so requires a centripetal force.

As this was a qualitative question it did not contravene the guidance that stated that banking problems would not be set.

### SL5/HL5

The performance of SL students in this question was the lowest on the paper and its discrimination was low, suggesting that for most it was guesswork. A larger proportion of HL students than SL students gave the correct answer. Approaching half of all the students gave answer A , thinking that doubling the radius would halve the terminal velocity.

### SL7/HL10

An easy question which was not answered very well and for which the discrimination was low, indicating that students were guessing. Similar questions in previous papers have produced similar results which suggests that giving the topic more attention may be beneficial.

### SL8/HL11

A feedback comment suggested that it was unclear whether the question refers to molecular density or mass density. It should be noted that the unqualified term density always refers to mass divided by volume. The majority of students answered that the density remained the same but a large number thought that the pressure would change.

### SL9/HL13

This question was answered well by HL students, less well by SL students but for both the discrimination was very good.

### SL12/HL17

The most frequent response by a considerable margin was D. 60% of the students who answered this question calculated wave speed rather than the particle speed.

### SL13/HL18

A straight recall question in which HL students performed significantly better than SL students, discrimination being good for both levels. The most frequent incorrect response was C which may have been the result of students confusing typical values of frequency and wavelength.

### SL15/HL20

Whether B is the only correct answer for a lightly damped system has been questioned in feedback. However, B is definitely the best answer and in multiple choice questions the best answer is the correct answer.

### SL18/HL26

There was little difference in the performance of SL and HL students in this question. Most discounted options C and D and opted for A or B in roughly equal numbers. It has been suggested that the question required the application of Lenz's Law, which is not on the SL syllabus but Lenz is not relevant here as the question asks for the initial current.

### SL19/HL27

In this question there was a significant difference in the performance of SL and HL students. The correct answer was given by 35% in SL and 51% in HL.

## SL only questions

### SL11

Performance in this question was fairly weak, A and D being the principal distractors.

### SL16

A feedback response queried the wording of this question, suggesting that it was unclear whether the final acceleration was that just before impact or upon collision. However, in such questions it is conventional that final velocity or final acceleration refers to the situation just before impact. The correct response was given by 66% of students with the remaining answers spread fairly evenly among the three distractors.

## HL only questions

### HL6

This was a well answered question with a high discrimination. The main distractor was B which could be obtained by using the final angular velocity rather than the average to calculate the number of revolutions.

### HL16

Many students did not know that the mass in an oscillating mass-spring system affects the frequency and kinetic energy but not the elastic potential energy resulting in the most frequent answer being D.

### HL23

The easiest question on the paper, with low discrimination.

### HL28

As no diagram was provided this question required the students to envisage the set-up. The most common answer C was is obtained by using B as the change in magnetic field rather than 2B.

### HL 35

The incorrect answer C, which was almost as common as correct answer B, is obtained when the effect of frequency on the intensity is ignored.

### HL38

Although this question had the highest number of blank responses it was well answered with good discrimination.

# Paper one b

## General comments

This paper focuses on assessing skills in the study of physics. It is identical for both SL and HL. This year, it contains two questions. Sub-questions are well-balanced between calculation and descriptive questions, and a wide range of assessment objectives is employed. Question 1 is set in the context of Current and circuits (B.5), and question 2 is set in the context of Gas laws (B.3). Questions do not rely on understanding outside the scope of the Physics Guide, Skills in the study of physics. The students had enough time to complete the paper, and most students were able to attempt all sub-questions. Discrimination is appropriate. Generally, the handwriting was of a similar standard to that in previous sessions; the answers were provided in the boxes, and additional answer sheets were used appropriately. The language versions of the paper are well-prepared.

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

Students, in general, proved an appropriate level of the skills examined. However, there was often a lack of detail in the answers. A high proportion of students were not well focused on the use of units and powers of ten. Even if we do not penalise wrong or missing units in most sub-questions, such mistakes often disrupt the student's fluency and lead to other, more serious errors. Another often seen careless mistake was ignoring the difference between radius and diameter. A lack of detail was also evident in the vague and often poor distinction between accuracy and precision. Frequently, there was a vague distinction between the uncertainty of a single measurement (uncertainty of the tool) and the uncertainty of a series of measurements (multiple readings), when assessing precision. More readings are usually taken to lower random uncertainty.

Difficulties related to the syllabus details include:

- Clearly communicate how to measure a length of about 0.5 m accurately.
- Calculate the area of a circle, and distinguish between the diameter and the radius.
- Use scientific notation in multiplication and division.
- Express fractional uncertainty as a unitless value.
- Extrapolate graphs, interpret graphs where the origin (0,0) is not shown.
- Identify outliers in the data.

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

Students, in general, proved the appropriate level of skills. Most students distinguished between absolute and fractional uncertainty effectively and presented fractional uncertainty as a unitless value or as a percentage uncertainty. Better-prepared students used significant figures, powers of ten, and units well in their answers. Most students demonstrated the ability to read graphs, plot a data point in the correct location on the graph, and draw the best-fit line.

Strong aspects related to the syllabus details include:

- Clearly communicate how to measure a length of about 1 mm accurately.

- Calculate the mean and range.
- Interpret scientific notation.
- Calculate percentage uncertainty.
- Work with fundamental units.

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

### Question 1. Length measurement and resistance

#### 1a

Many weak students mentioned lowering systematic error, which is not possible this way. Most prepared students correctly outlined increasing precision, reducing the effect of random errors, and checking uniformity of the wire.

#### 1b

Most students well suggested calliper or micrometer screw gauge as suitable for measuring diameter of the wire. In presenting a device appropriate to measure the length of the wire, many answers lack details. A short ruler or a tape measure in cm divisions is inappropriate here. Some students used a clear drawing to answer 1b ii), which is acceptable.

#### 1c

Better students identified the outlier, calculated the mean diameter from the five readings, and correctly calculated the absolute uncertainty and then the fractional, or percentage, uncertainty. The vast majority used the range of values, while only a few students used the statistical standard deviation (which was not required). Some students attempted to ignore the series of readings and estimated the uncertainty of the calliper, which led to a very low, unacceptable result. Some students incorrectly calculated in a way, as if repeated measurements would lead to increasing uncertainty. Fractional uncertainty in the length was generally well calculated.

#### 1d

Some students made a mistake in the use of the formula for calculating the cross-sectional area, taking the diameter instead of the radius, and some omitted to square the radius. Most students propagated relative uncertainties well. In the result, only better-prepared students rounded the absolute uncertainty to one (or two) significant figures and rounded the resistivity value to the appropriate number of decimals. Most of the well-prepared students used the power of ten correctly, in Ωm or Ωmm.

### Question 2. Graphing an isothermal process

#### 2a

Most students calculated the position of the missing point well and plotted it in the correct or acceptable place on the graph. Drawing a best-fit linear graph appears to be a problem for many students. For many of the lines drawn, it was observed that there was no attempt to draw a line where points are balanced about it. If a student takes one of the points as an outlier, the answer must clearly indicate it. A notable point is that a line going through the axes' crossing point was very rare. Part a iii) well discriminated between the best and average prepared students. Each of the three alternatives formulated in the markscheme was seen among the answers. Many students use the word "line" in the sense of a straight line, which is not recommended. Only a few students argued that the line does not pass through the origin, as it does not intersect at the point where the axes cross.

### 2b

Most students were able to answer this question well, but a reasonable number of students made a mistake on the power of ten or calculated the inverted fraction value incorrectly.

### 2c

Most students provided a correct answer; however, some calculated the amount of substance in mol, instead of the number of particles.

## Recommendations and guidance for the teaching of future students

Students were well prepared for this new format of paper. From the analysis of the answers this year, it seems that students score better if they:

- Distinguishes between the origin (0,0) and the point where the axes meet in the graph.
- Pay attention to powers of ten in calculations.
- Practice expressing their ideas in written form, in a logical manner, showing every step.
- Comment on their work, also in calculations, in verbal form, not only in symbolic form.
- Do not neglect units.

# Paper two

## General comments

With over 7000 students sitting for the exam in Higher Level (HL) and 4500 in Standard Level (SL), students' average mark in HL was 38.8 ± 19.5 and in SL 15.1 ± 9.6. The overall means in both levels were similar to previous years despite the change of syllabus and assessment scheme, even with a slight increase in HL.

So, as the mean mark has not seemed to be significantly different than in the previous years, it is possible to say that the more challenging structure with the 20-mark structured question/s at the end has been well received by the students. The effect of the syllabus change in the marks of the first examination session has not appeared to show any discontinuity in the performances.

As for the HL SL difference, usually present in exams, it can be said that the standard deviation, quite large in HL, seems to work in order to produce differentiation, a key objective of any exam.

Overall, the examination revealed clear distinctions between students' strengths in procedural problem-solving and some expected difficulties with conceptual reasoning and scientific communication (e.g. Wien's law vs the drag force acting on a satellite). While most students demonstrated confidence in direct calculations and standard applications of formulae, there was noticeable variability in their ability to explain physical processes in descriptive or theoretical terms.

In particular, students found a larger challenge when questions required them to connect macro phenomena with micro mechanisms (e.g., thermal conduction, entropy), predict outcomes, apply reasoning or draw inferences. These issues suggest that, while computational practice is embedded in instruction, greater emphasis should be placed on developing conceptual understanding, reasoning with models, and explaining physical ideas using precise scientific vocabulary, or questions involving real-life physics contexts (such as those on Q8 drag forces or energy losses) also highlighted a gap in students' ability to transfer theoretical knowledge to applied scenarios. This points to the need for more integrated teaching strategies that link physics concepts to authentic experiences and experimental observations.

Related to exam techniques, it is worth noting that a number of errors stemmed not from misunderstanding of physics content, but from lapses in those exam techniques: missing key terms in responses, misreading the intent of a question, or neglecting necessary quantities (e.g., omitting electron mass in Q7b). This indicates a continued need for examination literacy alongside conceptual instruction. Moving forward, teaching should not only prioritize content coverage but also focus on building students' interpretive skills, their ability to translate physical models into verbal and graphical explanations, and their comfort in tackling open-ended or unfamiliar contexts. Incorporating inquiry-based learning, collaborative experimentation, and structured reflection activities may better support the development of higher-order thinking skills required for success at this level.

General areas that need improvement:

Careful reading of the questions. Although many students did this successfully, it is a common issue in the weaker scripts.

General layout of answers within the answer box was sometimes poor. It is vital to emphasize the importance of a clear communication of the ideas presented.

Sequencing the presentation of facts to support an explanation or description. Although wording is not necessary, mathematical sequencing of ideas is often missing.

Steps in numerical working were sometimes missing, jeopardizing the possibility of getting full marks. Although final numerical answers are given full credit, an incorrect final answer will negate all marks if no previous steps are clearly shown.

Paying attention to the number of marks awarded for each part question. Particularly important in theoretical questions, this can always be taken as a hint of how to structure the answer.

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

- Describing mechanisms in microscopic terms, as in conduction in solids.
- The coherence condition for interference.
- Explaining conservation of energy in a fringe pattern.
- Mass defect and stellar energy calculations.
- Use of the Doppler effect for light.

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

- Kinematics, equations of motion and conservation laws in collisions.
- Application of Newton's laws and drag forces in particular.
- Electric field strength between parallel plates.
- Conditions needed for stellar fusion.

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

### 1a

With a performance of 55.1% in HL and 36.4% in SL, this easy start shows that some basic misunderstandings are present in several students, those who used conservation of momentum eventually just confirming that this was indeed a collision. Those who used conservation of kinetic energy easily scored full marks. The interesting thing with this question is that it was a question where students very rarely scored one mark so it is a good indicator of the percentage of students very well prepared for the exam in each level with a solid grasp of this basic understanding.

### 1bi

The calculation of the force on Y had the best performance for this question, so either solving correctly or scoring [1] by using correct equations with wrong data students showed basic understanding of force. It was interesting noticing that a few students used a different time interval, attempting to read it from the graph without realizing that it was given.

### 1bii

Students who understood here either used the energy obtained by Y or Force x average velocity. The key was to use an average so that error carried forward (ECF) marks could also be gained fully.

### 1biii

In general not very well done, the average out of 2 marks was 0.77 in HL and 0.44 in SL.

### 2a

The problem here was linked to comprehensive reading. Those who understood that the question was specifically about the mechanism, clearly mentioned in the stem, usually scored, in a clear majority with reference to conduction through a solid, via vibrations along neighbouring particles.

### 2b

1.52/2 in HL and 1.14/2 in SL showed that this was a successful question, in line with the above mentioned reference to procedural answers or calculations. Few made mistakes with the unit, sometimes using $W/m^2$ e.g. and very few in HL. A very minority went on to state the SI base unit, absolutely correct although not needed.

### 2ci

It was more successful in HL, 0.56/1 than SL, 0.32/1. Some very complete answers in HL.

### 2cii

1.62/3 and 1.16/3 show the performance of the students. In SL seems to have been where several students did not use Kelvin. In HL there were usually good attempts although not always successfully done. This was identified in the markscheme (MS) by awarding Marking Point 1 (MP1) if the temperatures were used in K.

### 2d only HL

Some very good answers, with a few identifying that the system was open and therefore an increase in the entropy of the room was possible. Most scored by analysing more traditionally and stating correctly the concepts related to entropy when only thermal energy is exchanged.

### 3a

Highest scoring of the paper with 91% and 80% getting the mark, again another case of calculations where students tend to perform well, particularly helped with the lack of penalization for units. Some powers of 10 errors.

### 3bi

1.30/2 vs 0/.71/2 showed a clear HL SL difference. In SL it seems that using wrong charges or masses was an issue, in HL those who attempted it usually scored full marks.

### 3bii

78% and 60% performances for this easy question where only a very few algebraic errors were seen in SL. It showed to be a good 3/4 boundary discriminator as it is indeed quite basic knowledge in a not simple scenario.

### 3biii

The help provided by asking students to state was not picked up, as even good students ended up with long calculations. It showed to be a good 6/7 boundary discriminator as it is a conceptual question demanding understanding.

### 3c

1.21 vs 0.70 showed again the gap between HL and SL. Some very good answers in HL with some either not realizing that forces were equal or making algebraic errors in SL.

### 3d

30% HL 15% SL got this mark by drawing a straight path.

### 4a

Low scoring question in both levels with 0.62 and 0.32 out of 2 marks. Even with a generous marking scheme, clearly there are problems with the understanding of coherence.

### 4bi

1.0 vs 0.39 showed a big gap between HL and SL. Many seem to have used a wavelength of difference instead of half although managed to use the equations correctly.

### 4bii

0.37 vs 0.24. Another good discriminator for 6/7 in HL as there were many good answers beyond those who just talked about waves cancelling not referring to the energy present in maxima.

### 4ci and 4cii

HL only about diffraction gratings, 0.40/1 and 0.80/3 showed that only good students were prepared in this topic. Another good 6/7 good discriminator for those who got n = 2.

### 5HL only a

0.68/2 not easy for students to apply their knowledge in this question that seemed to require reasoning beyond more than half of the students. Another example where challenging questions seem to be out of reach for many but in the end worked for discrimination.

### 5b

This was high scoring as it implied a direct analysis of the formula for the energy of a photon and its change in wavelength from the Compton formula.

### 5ci, ii, iii

The rest of the question was also linked to calculations so it allowed students to score, with about 70% overall scoring.

### 6 HL only a

Although students managed to score here, although getting the Lorentz factor was usually the typical mark as it was used correctly/incorrectly in about half the cases, part b i) and specially part b ii) showed very weak understanding of relativity and the use of spacetime diagrams, with b ii) being the lowest scoring question in the paper. A few excellent answers were seen, even using a fourth ALT that was added to the markscheme once found in students' papers.

### 7ai

Surprisingly low scoring for a question that draws very specifically from the guide. The factors were usually correctly identified with a few wrong references but both correct explanations were only present in strong students.

### 7aii

Although significantly higher than a i), it was slightly surprising to see a number of students who could not explain the equilibrium of the Sun in terms of forces, indicating perhaps an incomplete coverage of the syllabus. Question asked several times in the astrophysics option now in the common syllabus but clearly not covered by all appropriately.

### 7bi

Most were familiar with the calculation although many students, perhaps too many, forgot to include the mass of the positron. Students should be familiar with all the constants given in the booklet, and providing such information is a way of giving hints that would probably favour their total marks but not the discrimination ability of the test.

### 7ci, ii, iii

Clearly the most challenging part of the test. It seemed to be far from the SL reach and in HL it clearly allows for discrimination of the strongest students, as very good answers were seen.

### 7d

Interesting to see the success of this question, even coming after the previous challenging calculations. It does show a good attitude of students who keep reading and successfully answered this straightforward calculation.

### 7ei

Less than half the students identified here the Doppler effect, showing that a careful comprehensive reading is not fully exercised in the test. The same question, given the same information but asking about a calculation mentioning the Doppler effect would have been much more successful but would not allow for the discrimination that this one produced.

### 7eii

Often unanswered in SL, another good discriminator for 6/7 in HL. A few very good answers were seen.

### 8 HL only a

### 8ai and ii

Good manipulations to show the equations given were seen, although some just used a = v/t without any other reference and gained only [1] in a ii). Just more than 50% scored in a i), showing good skills here.

### 8bi

Quite a successful question where many managed to combine the orbital velocity with the sum of the energies to show what it was required.

### 8bii

The performance was of about 1.5/4 which shows that although many attempted the question, several students found it too challenging to somehow apply basic key concepts to this situation. Although very accurate answers were seen, a disparity of interpretations here were also seen, from the rocket finally landing on the Earth to remaining in elliptical orbit to escaping from Earth for a few.

### 8ci, ii, iii, iv

Quite high scoring in general although some got lost in the data given.

### 8 d

A nice finish for this question where over 40% managed to score full marks or gain at least [1] by ECF.