2021 Physics Subject Assessment Advice

Overview

Subject assessment advice, based on the 2021 assessment cycle, gives an overview of how students performed in their school and external assessments in relation to the learning requirements, assessment design criteria, and performance standards set out in the relevant subject outline. They provide information and advice regarding the assessment types, the application of the performance standards in school and external assessments, and the quality of student performance.

Teachers should refer to the subject outline for specifications on content and learning requirements, and to the subject operational information for operational matters and key dates.

School Assessment

Assessment Type 1: Investigations Folio

The Investigations Folio needs to include a minimum of two practical tasks and one Science as a Human Endeavour investigation. In the practical investigations, the students should have at least one opportunity to deconstruct a problem for which the outcome was uncertain. They should then design a method to investigate one aspect of this problem. The method should not just be a repeat of existing methods.

Assessment design criteria to be used for this assessment type are Investigation, Analysis and Evaluation and Knowledge and Application.

Teachers should ensure that they are making decisions based on the current subject outline and the current performance standards when assessing their students’ work.

The more successful responses commonly:

* completed a detailed deconstruction which investigated various aspects of an open-ended problem, fully utilising the four A4 pages permitted with deep consideration shown about the relevant physics concepts, variables that could be involved and several possible lines of enquiry. When a graphic organiser, like a mind-map, was used it enhanced the decision-making process and included justification about the key decisions made regarding the independent and dependent variables selected, the factors to be held constant (sometimes in a table format) and the equipment to be used to collect the data. (IAE1)
* used the deconstruction to be realistic about what is achievable in a classroom and whether that would help find an answer to the problem being investigated (IAE1)
* included a ‘blank’ data table in the proposed method, indicating how the potential independent and dependent measurements could be recorded (IAE1, IAE2)
* made a clear distinction between the four A4 page deconstruction and design ended and the investigation report started (KA4)
* identified safety and ethical issues and discussed how to overcome them (IAE1)
* included a detailed list of materials and equipment used (IAE1)
* proposed a hypothesis that predicts how an increase or decrease in the independent variable would affect the dependent variable, often including a discussion about proportionality (IAE1)
* contained a logical, detailed and justified procedure with a labelled diagram of the apparatus (IAE1)
* included all raw data in tabular format with appropriate headings, units and significant figures (IAE2)
* included a graph in at least one of the investigations, allowing students to show evidence of their understanding of the types of errors involved due to scatter of the data points around the line of best fit and to enable a justified conclusion about whether the relationship between the variables showed proportionality (IAE2, IAE3, IAE4)
* included evidence of correct quantitative analysis of the results (IAE3)
* presented justified conclusions that were consistent with the results and discussed whether or not the hypothesis was supported (IAE3)
* applied relevant physics concepts clearly and concisely to explain the results and the conclusion (KA2, KA4)
* discussed the reliability and validity of the experiment, including how the conclusion was affected by the limitations of the investigation, such as low sample size and factors that could not be held constant (IAE3)
* described errors that were specific to the equipment and data that was collected in the practical, clearly identifying and justifying them as random or systematic and explaining explicitly how they affected the data, including the graph (IAE4)
* correctly distinguished between the terms accuracy, precision and resolution when discussing the effects of errors on the data (IAE4)
* included a Science as a Human Endeavour investigation focussing on a contemporary scientific development, discovery or innovation with clear links to some relevant Stage 2 Physics concepts. One or two key concepts of Science as a Human Endeavour were identified in the introduction and elaborated on throughout the report to demonstrate a deep understanding of the interaction between science and society. The Physics concepts that were relevant to the focus of the investigation were applied clearly and concisely and a justified conclusion was presented. (KA3, KA4)
* correctly referenced factual statements in the investigations using a relevant and valid source (KA4)

The less successful responses commonly:

* consisted of a Folio that did not contain an investigation where the outcome was uncertain or just consisted of two completion practicals with minimal evidence that the student could deconstruct or design an investigation (IAE1)
* confined the deconstruction to a long introduction that was solely based on research about the known physics concepts and equation(s) for the investigation with minimal evidence of the process of deconstructing the problem to show that any other investigations were considered (IAE1)
* consisted of a brief deconstruction that made only a basic attempt to identify variables and factors to control with minimal justification about the decisions made regarding the selected variables, equipment to use and steps in the method (IAE1)
* consisted of a heavily scaffolded deconstruction that sometimes had a known outcome, such as the e/m electron ratio from the Teltron tube or the value of Planck’s constant, limiting the opportunity for a genuine deconstruction anywhere in the Folio (IAE1)
* contained investigations that changed multiple independent variables, making it difficult to present, analyse and form a clear conclusion from the data (IAE1)
* presented a brief set of steps for a procedure that did not describe what to record and how or what to change when repeating the trials (IAE1)
* omitted some of the requirements needed for a complete Folio, such as a hypothesis, identification of suitable variables, factors to control, safety considerations, a labelled diagram, a graph, a discussion of errors, or a conclusion that referred to the hypothesis (IAE1, IAE2, IAE3, IAE4)
* included tables of results that used significant figures inconsistently or lacked clear headings and units (IAE2)
* contained graphs that did not have axis labels or units (IAE2)
* only used tabulated data, rather than a suitable graph, with minimal analysis of how the results linked to the investigation (IAE2)
* incorrectly stated that any straight line of best fit on a graph proved that the two variables were directly proportional, rather than being linearly dependent. In some cases, this statement was given for curved lines of best fit (IAE3)
* focused on a highly statistical, mathematical analysis about the data in the table or graph without forming a clear conclusion or using the physics concepts to explain the results (IAE3)
* formed conclusions that were inconsistent with the results obtained (IAE3)
* discussed random and systematic errors without clearly differentiating between them, using only general terms for the errors, such as ‘human error’ or ‘poorly calibrated equipment’ (IAE4)
* incorrectly classified any errors relating to the procedure or equipment as being systematic errors (IAE4)
* discussed improvements that could be made to an investigation instead of discussing the effect of the procedure or errors on the data (IAE4)
* made little attempt to explain the effect of errors on the data except to categorize the impact of each error, such as being low, moderate or high (IAE4)
* made no distinction between the terms accuracy and precision and demonstrated confusion about how they were effected by random and systematic errors (IAE3, IAE4)
* were limited to very broad statements such as “random errors impacted the precision of the practical” (IAE4)
* limited the Science as a Human Endeavour investigation to a history report about an invention or a description of how a piece of technology had developed over time or presented an Issues Investigation that was merely a discussion about the advantages and disadvantages of the topic selected (KA3)
* produced a Science as a Human Endeavour report with minimal attempt to explain any physics concepts (KA1, KA2, KA4)
* produced a Science as a Human Endeavour report that failed to identify the Science as a Human Endeavour concept being explored (KA3).

General comments about the evidence:

Annotations to support teacher judgement against the relevant Assessment Design Criteria were helpful when considering large complex assessment items.

The specific features on the PSR should be congruent with those that have been assessed in the tasks and with what is recorded in the LAP. Grades should not be awarded for specific features that are not assessed in the Folio.

Many teachers did not record their assessment of KA3 in AT1, even though this is the major Assessment Type for the assessment of this specific feature and it appeared to have been assessed in at least one task.

Assessment Type 2: Skills and Applications Tasks

Three or four Skills and Applications Tasks provide evidence of students’ knowledge, understanding, and application of science inquiry skills, key physics concepts, and the connections with science as a human endeavour by discussing the interaction between science and society.

Subject outlines provide specifications about the number of assessments required for each assessment type. Careful consideration has gone into these specifications with recognition that students have assessment demands across a number of subjects. It has been evident through moderation that some classes have undertaken more than the maximum number of assessments for Assessment Type 2.   Teachers are reminded that the Learning and Assessment Plan will inform the assessment of students across the full year. If a variation is made to this learning and assessment plan, the number of assessments that students undertake for an assessment type *should not exceed* the maximum prescribed in the subject outline unless there is an appropriate special provisions reason for requiring the class to undertake a replacement assessment.

Assessment design criteria to be used for this assessment type are Investigation, Analysis and Evaluation and Knowledge and Application.

These tasks do not carry individual weightings.

The more successful responses commonly:

* showed all working when applying formulae by including steps for rearrangement and substitution (KA1, KA2, KA4)
* demonstrated a deep understanding by clearly applying, explaining or describing physics concepts that were relevant to the question, especially in new contexts (KA1, KA4)
* used vector diagrams correctly and included clear labels (KA1, KA2, KA4)
* were more evident in a well-designed set of SATs that presented a variety of question difficulties and instructions such as: state, describe, determine, calculate, draw, derive, explain; including some science inquiry skills and Science as a Human Endeavour questions. (KA1, KA2, KA3, KA4)

The less successful responses commonly:

* did not show steps in forming an answer that involved calculations (KA1, KA2, KA4)
* showed a poor grasp of vector subtraction or addition (KA1, KA4)
* tried to apply irrelevant formulae (KA1, KA2)
* ignored unit conversions or made errors when rearranging formulae or calculating answers (KA2)
* gave an irrelevant answer that was based on a lack of comprehension about what the question was asking (KA1, KA2)
* did not use physics concepts to answer the question (KA1, KA2)
* were hampered because students were required to answer questions from content that was outside the current course.

Teachers should note that:

* A good set of SATS should provide opportunities to enable students to demonstrate evidence across a significant proportion of the course at the full range of grade levels, including their understanding of Science as a Human Endeavour and some Science Inquiry Skills.
* SATS which consisted primarily of applying formulae restricted the amount of deep and coherent communication students could show about physics concepts.
* SATS should include content from the recent additions to the course and omit sections that have been removed from the course.
* The decision to award particular grades within the performance standards cannot be made by simply equating test percentages to grades.
* A decision for a particular specific feature such as IAE2, should not be based on a single short answer question in one Skills and Applications Task. There needs to be significant evidence across the tasks to assess the level of the student work against a specific feature.

External Assessment

Assessment Type 3: Examination

There are often many questions in the external examination which require students to 'show' that a particular value is correct. Students need to ensure that the calculation that they undertake gives the value stated in the question. If a student shows a calculation which does not give the result required then they need to acknowledge this, and if time allows, repeat the question to obtain the value. Questions that require students to 'show' that a quantity is correct that involves trigonometric calculations also serve as a reminder for students to ensure that their calculator is set to degrees instead of radians.

Students need to use significant figures throughout the examination. When calculating numerical quantities students need to give their final answer to the lowest number of significant figures used in the calculation. Similarly, students need to take care when reading values from a graph – it is unlikely that these values can be determined correct to three significant figures. Students should give their answers using scientific notation for very large and very small numerical quantities. Similarly, students need to take care when reading values from a graph – it is unlikely that these values can be determined correct to three significant figures. Students should give their answers using scientific notation for very large and very small numerical quantities.

The 2021 external examination highlighted areas of the course that require further attention. Students need to be able to distinguish diffraction grating experiments and double slit experiments; use the conservation of baryon and lepton numbers to solve problems within the Standard Model; understand how measured time intervals related to different frames of reference; and explain how induced emfs and currents relate to Faraday's Law and Lenz's Law.

Question 1

The more successful responses commonly:

* showed all substitution and rearranging in part (a)
* stated any assumptions made
* clearly linked the drag force/air resistance in part (b) to increased acceleration downwards/greater net force acting downwards and the time of flight of the projectile.

The less successful responses commonly:

* did not show appropriate substitution and rearrangement
* did not adequately show the correct answer for (a)(ii). Here, students need show that their calculation results in a time of 0.702. Many students included negative values which would not give the required value for time.
* did not give sufficient detail in part (b) to form an 'explanation' – many were simply 'descriptions'
* did not adequately show the correct answer for (a)(ii). Here students need show that their calculation results in a time of 0.702. Many students included negative values which would not give the required value for time.

Question 2

Many students did not attempt part (a) of this question. This was surprising given the number of students who went on to answer the rest of the question correctly. Students are encouraged to take their time when answering questions to ensure that they do not miss any relevant information. Sketching electric fields continues to be an area of weakness for students — both in the shape and direction of the field. Otherwise, this question was answered generally well with some students making errors with their calculators rather than their conceptual understanding or working.

The more successful responses commonly:

* sketched parallel field lines directed upwards for part (a)
* showed the conversion from GV to V in their working.

The less successful responses commonly:

* did not attempt part (a)
* attempted to use Coulomb's Law to determine the electric field strength or force on an electron within the field in parts (b) and (c). Students need to be aware of the circumstances where Coulomb's Law is appropriate
* used  then  to calculate the force. While this gives the correct value for the force, it adds an unnecessary layer of calculations.

Question 3

The calculation parts, (a)(i) and (b)(i), of this question were mostly answered correctly. Unfortunately, the direction of the magnetic field produced by a current-carrying conductor and force on a moving charged particle within a magnetic field still proves to be challenging for students.

The more successful responses commonly:

* showed the substitution of  in their calculation
* stated any assumptions made.

The less successful responses commonly:

* attempted to use in part (b)(i)
* gave incorrect answers for (a)(ii) and (b)(ii) such as 'clockwise' or 'anticlockwise'.

Question 4

This question was generally answered well. Most students were able to recognise that Krypton was the element most likely found in the outer gas layers of the Sun as all of the frequencies of the emission spectrum of Krypton formed a subset of the Fraunhofer lines.

The more successful responses commonly:

* clearly stated 'Krypton' as the correct answer
* explained clearly the relationship between the emission spectrum of Krypton and the Fraunhofer lines.

The less successful responses commonly:

* attempted to use the 'brightness' of the lines to answer the question
* attempted to compare the number of emission lines of iron and krypton to answer the question.

Question 5

This question was generally answered well by students. Most students were able to correctly calculate the work done by the charged particle and rearrange the expression for the kinetic energy of the particle. Students need to show all rearrangement and substitution in order to obtain full marks.

The more successful responses commonly:

* substituted values correctly
* showed the rearranged expression for the mass algebraically before substituting values
* used the appropriate number of significant figures

The less successful responses commonly:

* did not convert 50 kV to 50,000 V
* did not show the calculation of mass, suggesting that an equation solver on a calculator was used
* neglected to use the '2' in the formula for the kinetic energy.

Question 6

Students continue to find calculating the gravitational force between two objects difficult particularly when conversions are required. Students often forgot to square the radius or substituted 9.80 for G. Students also had difficulty articulating how the gravitational forces were consistent with Newton's Third Law, with many students offering broad statements of the law as their entire response. Many students had difficulty answering part (c) – either by using Kepler's First or Third Law or by providing an explanation that included more than one law.

The more successful responses commonly:

* converted the separation to *m*
* explained in part (b) that both Mars and Mangalyaan exert a gravitational force on the other that are equal in magnitude and opposite in direction
* used Kepler's Second Law to explain that the time taken from A to B is much less than the time taken from B to A
* used the diagram in (c) to assist their explanation of the time taken between each of the points.

The less successful responses commonly:

* stated Newton's third law as 'every action has a reaction' or similar
* did not clearly explain that there are two forces acting in opposite directions — the force of Mars on Mangalyaan and the force of Mangalyaan on Mars
* did not explain which of Kepler's Laws were being used
* did not adequately link their discussion to the time taken to move between the points.

Question 7

Both parts of this question proved to be challenging for students. First, students did not give appropriate detail in their explanation of why the electrons undergo uniform circular motion. Students were able to state that the electrons experienced a force perpendicular to the velocity of the electrons but did explain this clearly. Many students described a 'right hand rule' which is helpful for determining the directions of F, v, and B but it is not a physical law. Many students also did not explain that the force acting on the electron caused an acceleration that resulted in a change in direction only, so that the electrons moved at a constant speed. In part (b) many students gave unrealistic values for the speed of the electrons, such as well beyond the speed of light or almost stationary. Students need to have an awareness of the reasonableness of their calculated values and determine if an error was made.

The more successful responses commonly:

* explained that the force due to the magnetic field, velocity of the electrons, and direction of the magnetic field were mutually perpendicular
* described the conditions for uniform circular motion.

The less successful responses commonly:

* attempted to use 'right hand rule' as an explanation for uniform circular motion
* rearranged incorrectly and substituted incorrect values
* obtained physically impossible values for the speed of the electron
* conflated speed and velocity.

Question 8

This question proved to be difficult for students, particularly if the Science Inquiry Skills were not practised or taught explicitly throughout the school year. The first common issue for students was identifying a variable that could be meaningfully investigated. Many students were not clear about the variables that were chosen (e.g. radius, tension) or suggested variables that were not able to be manipulated (e.g. acceleration due to gravity). The second common issue for students was articulating a method that could be undertaken in most classrooms. The method provided by the students needed to be clear and logical, and clearly state how variables would be manipulated, measured, or controlled.

The more successful responses commonly:

* stated clearly the variables to be investigated
* provided a clear description of how independent and dependent variables would be measured and manipulated
* explained that at least five different increments for the independent variable needed to be tested
* explained that three trials for each increment were required, and those three values were then averaged to reduce error
* provided clear steps in their investigation
* described scientific equipment in their method (e.g. light gates, stopwatch, etc.).

The less successful responses commonly:

* described unrealistic methods (e.g. completing the experiment in a vacuum, changing gravitational acceleration)
* attempted to describe the expected results using a formula, but not providing a method
* selected appropriate variables but did not appear to understand the physics required to design an experiment
* did not address accuracy or precision within the method
* focussed on a possible conclusion to the experiment rather than explaining a method.

Question 9

Science as a Human Endeavour (SHE) questions continue to be difficult for students. These types of questions require students to think carefully about the context and then describe how SHE is evident in the context. Students need to use the text to support their description, while also providing their own insights or making links from across different parts of the text. Unfortunately, many students simply wrote quotes from the stem of the question underneath a heading of one of the SHE strands. Many students also did not state which strand they were using in their description which affected understanding their response and the marks that could be awarded. In part (b) many students did not calculate the orbital radius for the speed. Like other questions in the exam, this 'show' question needs to have a matching calculation – many students stated an incorrect calculation that gave the correct result. A number of students used Kepler's Third Law for part (b)(ii) and were awarded full marks for this question.

The more successful responses commonly:

* stated the SHE strands.
* explained the SHE strands in the context of Capella Space.
* made links across the text to assist their description of the SHE strands.
* explained the SHE strands in their own words and suggested links from outside the text.
* linked the context to data, knowledge, and technology.
* calculated the orbital radius correctly.

The less successful responses commonly:

* did not state explicitly which SHE strands were being discussed.
* copied text from the question rather than formulating their own response.
* did not describe the SHE strands as prescribed in the Subject Outline
* did not substitute correctly.
* did not compare the calculated value to that required in the question.

Question 10

This question also proved to be challenging but for different reasons to those outlined in other questions. It was apparent from the student responses that many students are being taught to answer physics questions using content from outside the Subject Outline. Many students had attempted to memorise the Paschen, Balmer, and Lyman series to answer these types of questions. Unfortunately, many of the students had not memorised these correctly and consequently lost marks in part (a). Similarly, many students had been taught to solve these problems by memorising the energy levels of hydrogen but did not have the correct values. Many students also attempted to use the relationship between the energy levels of hydrogen  but had not remember this formula correctly or how to apply it appropriately. Regardless of which of these methods were attempted it must be emphasised that students need to learn to solve problems in the Physics course using content and formulas from the Subject Outline. It is unreasonable to expect students to remember formulas from outside the Subject Outline when a good conceptual understanding of the context and the physics content is sufficient for problem solving. This question also highlighted some misunderstandings of energy levels with many students incorrectly assuming that 656 *nm* and 410 *nm* were infrared and ultraviolet respectively.

The more successful responses commonly:

* linked the wavelength to the energy of the photons emitted
* linked the energy of the photons to the energy levels of hydrogen.

The less successful responses commonly:

* converted joules to electron volts incorrectly
* attempted to determine energy levels by subtracting the wavelengths in the emission spectrum
* did not calculate the frequency of the photons
* did not convert *nm* to *m*.

Question 11

This question proved to be difficult for students. Students found it difficult to articulate how the alternating current in the transmitting coil produces an alternating magnetic flux through the receiving coil. This alternating magnetic flux induces an emf and therefore alternating current in the receiving coil and charges the battery. Many students attempted to rephrase the question in (a) to form their response without linking any of the key concepts. Part (b) was a little more successful, however many students did not use appropriate physics terminology in their responses.

The more successful responses commonly:

* linked the alternating current to alternating magnetic field
* made alternating magnetic flux the focus of their response
* used Faraday's law and Lenz's law to articulate their understanding.

The less successful responses commonly:

* discussed area instead of distance in part (b)
* missed the connection between the transmitting coil and receiving coil
* attempted to use a formula to answer the question.

Question 12

This question produced a range in responses from students. Many students chose to focus on other aspects of the production of laser light (such as population inversions, fluorescence) when it was not relevant to this question. A significant portion of the students discussed stimulated emission in terms of photons incident on the atom, but few explained that the incident photon needed to be identical (same energy) as the emitted photon and therefore difference between energy states. Part (b) was generally answered well by students. A small number of students did not convert electron volts correctly.

The more successful responses commonly:

* explained the energies of the photons clearly
* used a diagram to assist their explanation
* used the concept of a metastable state.

The less successful responses commonly:

* discussed irrelevant physics content
* discussed how electrons to were raised to excited states
* did not convert electron volts to joules correctly.

Question 13

The explanation parts of this question were challenging for students. In part (a)(i) many students found it difficult to explain the existence of a maximum frequency concisely. Some students spent considerable time discussing work through an electric field or the significance of the potential difference and did not answer the question. A significant number of students were able to link the potential difference and work to energy but struggled to explain why there exists a maximum energy. Others misinterpreted part (a)(i) completely and discussed the images produced by x-rays. Similarly, in part (b) students were able to state a correct adjustment to the x-ray tube but were unable to explain why this adjustment had the desired effect. Many students conflated frequency and intensity of x-rays. In contrast, part (a)(ii) was answered very well with most students achieving full marks.

The more successful responses commonly:

* linked the energy of the electrons with the potential difference across the x-ray tube
* explained that the maximum kinetic energy of the electrons depended on the potential difference
* linked the energy of electrons to the energy of the photons
* linked the energy of the photons to the frequency of the photons
* converted electron volts to joules correctly
* linked the adjustment to the x-ray tube to the photons emitted
* linked the photons emitted from the adjustment to the quality of the image produced
* used appropriate terminology throughout.

The less successful responses commonly:

* did not keep their explanations concise
* focussed too much on using formulas to explain the physics concepts
* explained the production of x-rays but did not give sufficient attention to explaining why the frequency of the emitted x-rays has a maximum value.

Question 14

This question was generally answered well. Most students were able to read the threshold frequency from the graph, but some students misunderstood what was required and instead calculated the gradient. A small number of students misread the scale to give an incorrect value for the threshold frequency. Part (a)(ii) was also generally answered well with most students using the correct formula to determine the work function. A small number of students did not convert to electron volts correctly. Part (b) proved to be challenging as many students were not able to distinguish accuracy and precision. In this question, the focus was not the answer (accurate or inaccurate) but instead on the arguments given to support the position taken. Part (c) was also generally answered well, with many students being awarded full marks. Conversions continued to cause difficulties for students.

The more successful responses commonly:

* read the threshold frequency off the graph correctly
* converted joules to electron volts
* discussed accuracy by comparing the difference in the two values of the work function as a proportion of the accepted value
* provided a detailed response that addressed accuracy.

The less successful responses commonly:

* misread the scale on the graph
* focussed the discussion of accuracy as higher or lower values
* obtained negative values for kinetic energy

Question 15

This question also produced a variety of responses. In part (a) many students lost marks by not including the scale factor for the charge of the particles or by not squaring the separation. Part (b) revealed the variety of ways in which proportionality is taught in different contexts. None of the methods used are more correct than any other, however the students that used the simplest methods tended to achieve full marks for this question. Many students did not use proportionality and simply calculated the value of the force and so did not receive full marks. Part (c) also appeared to be difficult for students as many did not recognise that the forces acted in opposite directions. It is important that all relevant working be shown for any question in the exam as many students stated an incorrect answer for this question but may have been awarded a mark if working was shown.

The more successful responses commonly:

* used scale factors correctly
* ensured that proportionality was used exclusively in part (b)
* showed that the student understood the vector nature of the forces
* showed all appropriate working.

The less successful responses commonly:

* did not square the separation
* added the magnitudes of the forces in (c)
* stated answers without any working/justification.

Question 16

This question showed significant variation in the quality of the responses by students. Drawing and labelling vectors continues to be a difficult skill for students to master. It appeared that many students were not familiar with this style of question as many responses did not refer to the diagram at all. Similarly, many students did not understand the significance of the difference in mass of the pucks when drawing vectors. Part (b) was generally answered better than (a) but students also need to state the law conservation of momentum and explain it in context to show depth of knowledge and understanding.

The more successful responses commonly:

* labelled vectors correctly
* used the grid to determine the relative magnitudes of the vectors
* took the mass of each puck into consideration when drawing vectors
* used the vectors to clearly explain that momentum was conserved
* clearly showed the vector addition
* used the vectors to clearly explain that momentum was conserved
* stated the conservation of momentum explicitly.

The less successful responses commonly:

* used a ruler to measure distances
* did not consider the two-dimensional nature of the diagram
* did not use appropriate notation
* did not refer to the conservation of momentum
* did not consider the two-dimensional nature of the diagram
* did not use appropriate notation.

Question 17

This question proved to be difficult for students. This was a newer style of question for the examination – less directed and more focussed on experimental knowledge and understanding in context. Most students were awarded marks for this question, but very few achieved full marks. Many students did not use the scale diagram to calculate the distance between maxima. It is important for students to recognise that the diagram is a scale diagram but that does not mean that it is a 1:1 scale. The ruler was in the question to provide the scale for measuring the distance between maxima. Most students misinterpreted the problem as a double-slit interference and proceeded to use the wrong formula for the subsequent calculations. Students also need to ensure that their calculator is on the degrees setting for trigonometric calculations. Many of the questions in the earlier parts of the exam – particularly the Q1 of book 1.

The more successful responses commonly:

* used the scale diagram in the question
* understood that the question was a diffraction grating context
* used trigonometry appropriately.

The less successful responses commonly:

* used the radians setting on the calculator instead of degrees
* used the formula for the distance between adjacent bands in the double-slit experiment
* did not use appropriate notation.

Question 18

This question highlighted some misunderstands in the Standard Model – particularly the nature of subatomic particles and the conservation laws. To determine the nature of particle X in part (a) students needed to systematically work through each of the particle types and conservation laws to eliminate incorrect answers. Students needed to eliminate baryon (by recognising that both the sigma particle and neutron are baryons) and lepton (as the lepton number would not be conserved) to arrive at meson as the correct answer.

Unfortunately, many students did not appear to understand that meson was a possibility due to misunderstandings about the possible charges and baryon numbers of mesons. Part (b) was generally answered better, but still showed that this continues to be a part of the course that requires greater emphasis. Students needed to determine the charge of the sigma particle then use the conservation of charge to arrive at the correct solution. Many students did not determine the charge of the sigma even though the quark combination was given.

The more successful responses commonly:

* used the conservation laws appropriately in (a)
* calculated the charge of the sigma particle.

The less successful responses commonly:

* did not systematically work through possible solutions for (a)
* stated an answer without any justification in both (a) and (b)
* did not determine the charge of X using conservation laws.

Question 19

Parts (a) and (b) of this question were fairly challenging for students but (c) and (d) were more straightforward. Students usually find derivations difficult, particularly derivations of formulas that they have not seen before. Here, students were able to use the de Broglie relations appropriately but did not communicate the change in momentum of the photons with sufficient detail. Students need to link the magnitude of the change in momentum to the change in direction more explicitly. Most students were awarded marks for part (b) but very few were awarded full marks. Many students did not take the total number of photons into account and only calculated the force exerted by a single photon. Most students calculate the Lorentz factor correctly but did not show the correct working (e.g. missing squared values for velocity or c). Part (d) was also generally answered well, but many students did not appear to understand the frames of reference. In this case, the time measured on the spaceship is to (as the spatial coordinates of the spaceship are fixed in this frame of reference) and the time measured on Earth is t (as the spatial coordinates are not fixed in this frame of reference). Once this understand is reached the solutions is straightforward, but there were some errors in rearranging.

The more successful responses commonly:

* explained each step in the derivation in (a)
* explained how the magnitude of the change in momentum was determined
* recognised that the formula in (a) was necessary for (b)
* showed the correct substitution of values to determine the Lorentz factor
* showed a good understanding of frames of reference.

The less successful responses commonly:

* did not consider the change in direction of the photon in (a)
* did not take into account the total number of photons in (b)
* did not substitute values correctly in (b)
* calculated the incorrect time for (d).