# SACE Board Logo2024 Physics Subject Assessment Advice

Overview

This subject assessment advice, based on the 2024 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. It provides information and advice regarding the assessment types, the application of the performance standards in school and external assessments, and the quality of student performance.

The Subject Renewal program has introduced changes for many subjects in 2025; these changes are detailed in the change log at the front of each subject outline. When reviewing the 2024 Subject Assessment Advice, it is important to consider any updates to this subject to ensure the feedback in this document remains accurate.

# School Assessment

Teachers can improve the moderation and online process by:

* combining all tasks for a single folio into one single pdf
* providing evidence to support the grade awarded in each task, including marks awarded for questions in SATs.

Assessment Type 1: Investigations Folio

The Investigations Folio should include one or two practical investigation tasks and one Science as a Human Endeavour investigation. Assessment design criteria to be used for this assessment type are Investigation, Analysis and Evaluation, and Knowledge and Application.

Teachers can elicit more successful responses by:

* ensuring that at least one task in the investigations folio enables students to present a full deconstruction that shows wide-ranging consideration of several lines of enquiry to a problem for which the outcome is uncertain
* making it clear to the students that the Science as a Human Endeavour report should be based on a contemporary focus, include some Stage 2 Physics concepts, and discuss clear links to the SHE strands and some of the elaborations within the SHE concepts
* ensuring students have a clear understanding of the word limits (and font size requirements), and what evidence is included in the word limit, for each task
* avoiding practical investigation tasks that require all students to follow a set method to take measurements and make calculations to confirm a value, rather than investigating a problem where students can select and investigate an independent variable and measure how it affects a dependant variable to solve a problem.

The more successful responses commonly:

* clearly separated the evidence of deconstruction from the practical report, using up to four sides of an A4 page (minimum font size 10) as specified in the subject outline (IAE1)



* included at least one detailed deconstruction question for which the outcome was uncertain, and considered a wide range of perspectives, showing several possible lines of enquiry and justification for some of the key selections made in forming the design regarding the independent and dependent variables selected, the factors to be held constant, and the equipment selected to collect the data (IAE1)
* contained a table of factors to control, including headings of ‘what is controlled’, 'how controlled', and 'why controlled' (IAE1)
* contained a clear method, in step-by-step form, with a justification of each step (IAE1)
* included a suitable graph in at least one of the investigations, with a line of best fit extrapolated back to the axis intercepts where appropriate, enabling students to show evidence of their understanding of random errors, precision, and the scatter of the data points around the line of best fit, and enabling a justified conclusion about whether the relationship between the variables showed proportionality (IAE2, IAE3, IAE4)
* contained data tables that were effectively and concisely presented, with clear and correct headings, units, and use of significant figures (IAE2)
* applied meaning to the gradient of the line of best fit by linking it to a physics relationship, demonstrating systematic analysis of the results (IAE3)
* presented justified conclusions that were consistent with the results, discussing whether or not the hypothesis was supported in the context of the original problem (IAE3)
* described systematic and random errors that were specific to the equipment and procedure that had a significant impact on the data and then clearly explained the impact that the errors had on the data, scatter of data points, and trendline, correctly linking systematic errors to accuracy and random errors to precision (IAE4)
* presented the error evaluation in a table with columns for 'error', ‘impact on data', and 'evaluation of procedure', aligning the student work directly with what is assessed in the performance standard (IAE4)
* included calculations in analysing practical investigations and described the extent of the impact of errors on their confidence in the results in terms of precision, accuracy, reliability, validity, and the limitations, such as factors that could not be held constant or a low sample size (IAE3, IAE4)
* applied relevant physics concepts clearly, coherently, and concisely to explain the results and the conclusion (KA2)
* included a Science as a Human Endeavour report where some Stage 2 Physics concepts were applied, and where SHE strands and elaborations were clearly identified and then meticulously discussed in relation to the topic selected (KA3)
* used and referred to suitable diagrams and images in reports to demonstrate a process or support conceptual explanations (KA4).

The less successful responses commonly:

* missed key elements, 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)
* did not include a separate deconstruction, contained a deconstruction that was part of an appendix in the report, or exceeded the 4-page limit (IAE1)
* contained a deconstruction with little discussion about the possible variables or had experimental designs without justification of key decisions (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)
* consisted of a folio with investigations that only had a known outcome, such as confirming a laser wavelength, rather than one where the outcome is uncertain (IAE1, IAE4)
* included tables of results that used significant figures inconsistently or lacked clear headings and units (IAE2)
* neglected to include a graph in the whole investigations folio, used graphs that were not based on the two variables being investigated, or had less than 5 data points with no trendline, restricting the analysis (IAE2)
* made no attempt to analyse results to look for proportionality or linear dependence, especially when a trendline should have been included in the practical investigation (IAE3)
* discussed random and systematic errors without clearly differentiating between them, using only general terms for the errors, which were not specific about the equipment being used in the investigation, and provided no discussion about the impact of errors on the results (IAE4)
* made no distinction between the terms ‘accuracy’ and ‘precision’ and demonstrated confusion about how they were affected by random and systematic errors (IAE4)
* dedicated long sections to discussing ‘improvements to the practical’, which is no longer in the performance standards, instead of describing how specific errors had affected the data (IAE4)
* were based on SHE task sheets that contained suggested topics that were not suitable, or contained student responses that needed more guidance and feedback to encourage the students to focus on the SHE concepts and some relevant Stage 2 Physics concepts (KA1, KA2, KA3, KA4)
* lacked detail or connection to Stage 2 Physics concepts in either the practical investigations or the SHE report (KA1)
* contained a SHE report with only SHE strand headings and very little depth of discussion about the strands or the elaborations (KA3)
* contained a SHE report that only discussed the history of the development of a piece of technology or how a piece of technology was being used in society under the guise of application and limitations, rather than showing an understanding of how science was impacting society (KA3)
* included a long discussion about the physics concepts and the parts that made up a piece of technology, with little discussion about the interaction between science and society (KA3)
* failed to include any references (KA4).

Assessment Type 2: Skills and Application 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.

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.

Teachers can elicit more successful responses by:

* ensuring that a set of SATs are well-designed, covering large sections of the course, including some science inquiry skills and Science as a Human Endeavour questions. The questions should include an appropriate range of question complexity and should provide opportunities for students to become familiar with command terms used in examinations such as ‘state’, ‘describe’, ‘determine’, ‘calculate’, ‘draw’, ‘derive’, ‘show’, and ‘explain’ (KA1, KA2, KA3, KA4, IAE2, IAE3, IAE4)
* avoiding creating SATs completely formed from past examination questions. These questions are available in the public domain in various formats (revision guides and online copies of examinations), and it is likely the highest performing students will have used these in preparation for SATs (KA1, KA2, KA3, KA4)
* considering the amount of evidence present for each performance standard when designing SATs and when making assessment judgments as some tasks seemed to be heavily weighted in practical skills (KA1, KA2, KA3, KA4, IAE2, IAE3, IAE4)
* including a set of solutions for SATs to clarify the expected responses for each question (and question parts). This supports the moderator to understand the allocation of marks and the alignment to specific features being assessed.

The more successful responses commonly:

* included clear, detailed, and correct responses to a range of physics concepts and questions of differing types and levels of difficulty (KA1)
* contained written responses that applied the correct physics concepts to answer the question posed, providing sufficient detail to obtain the number of marks assigned to the question (KA1, KA2, KA4)
* showed all working when applying formulae by including steps for rearrangement and substitution, using clearly labelled and correct vector diagrams when needed (KA1, KA2, KA4)
* clearly described and correctly applied some SHE strands and elaborations for Science as a Human Endeavour questions (KA3)
* used clear, carefully drawn, and labelled diagrams, including arrow heads for vectors (KA4).

*The less successful responses commonly:*

* did not show substitution or rearrangement steps in forming an answer that involved calculations or tried to apply irrelevant formulae or incorrectly rearranged formulae or did not convert units correctly (KA1, KA2, KA4)
* had issues with handwriting that was too difficult to read (KA1, KA2, KA4)
* had many blank or incorrect responses to questions or gave an irrelevant written answer that was based on a lack of comprehension about what the question was asking (KA2, KA4)
* gave minimal reference to physics theory when communicating written responses (KA1, KA4)
* used vector diagrams incorrectly or used them without arrows or labels (KA1, KA4).

# External Assessment

Assessment Type 3: Examination

The 2024 Physics examination highlighted many strengths and areas of growth for students, and aspects of the course that require further attention by teachers. Before analysing each question individually, some of the more general themes across the examination will be covered.

The more successful responses commonly:

* used the correct number of significant figures
* included units of physical quantities in the final answer for each question
* showed correct working (rearrangement and substitution of numerical values) for each question that required a calculation
* stated any assumptions needed to answer questions
* used images or diagrams to assist explanations
* were able to distinguish between an explanation (a physics-based justification of phenomenon) and a description (physics-based statements of phenomenon).

*The less successful responses commonly:*

* did not show all working
* gave final calculations to an incorrect number of significant figures
* provided descriptions rather than explanations for ‘explain’ questions
* provided an incorrect calculation for a ‘show’ question but stated the correct solution
* did not provide units for quantities
* calculated quantities incorrectly
* did not attempt every question.

Question 1

This question was a straightforward opening question to the examination and was the question that resulted in the most students being awarded full marks. The conversion in the question was not difficult and proved to be a positive question to begin Book 1.

The more successful responses commonly:

* showed correct rearrangement for Parts (a) and (b)
* correctly substituted numerical values
* showed the conversion from GHz to Hz in Part (b)
* used the correct units for wavelength in (b).

The less successful responses commonly:

* incorrectly rearranged the formula in (a)
* assigned units to the number of loops in the input coil in Part (a)
* did not enter the values correctly into a calculator in Part (b).

Question 2

This question proved to be effective in differentiating student knowledge and understanding. The responses were quite mixed, suggesting that students need to be more precise with physics language and terminology. The better responses to this question clearly articulated two distinct explanatory points related to normal forces and centripetal acceleration.

The more successful responses commonly:

* stated explicitly that the horizontal component of the normal force causes the car to undergo centripetal acceleration
* clearly stated the centripetal acceleration produced by the horizontal component of the normal force reduces the need for friction to provide centripetal acceleration.

The less successful responses commonly:

* only discussed the normal force in general, rather than specifying the horizontal component of the normal force
* did not use appropriate physics terminology (e.g. the car ‘moves’ rather than the car ‘undergoes centripetal acceleration’).

Question 3

This question was generally answered well with most students being awarded full marks. Students may have answered (a)(ii) using either $v=\sqrt{\frac{GM}{r}}$ or $T^{2}=\frac{4π^{2}}{GM}r^{3}$ , although students tended to make more errors if using $T^{2}=\frac{4π^{2}}{GM}r^{3}$.

The more successful responses commonly:

* substituted values correctly in Part (a)(i)
* rearranged correctly in Part (a)(ii)
* rearranged the formula in Part (a)(ii), then substituted values into the rearranged formula
* calculated the force in (b) as $2.67×10^{20}N$.

The less successful responses commonly:

* did not square π in (a)(ii)
* did not cube the separation between Saturn and Tethys in (a)(ii)
* did not square the period of Tethys in (a)(ii)
* stated an incorrect expression for the mass of Saturn in (a)(ii) but wrote the correct value of the mass of Saturn in (a)(ii)
* did not square the separation between Saturn and Tethys in (b)
* calculated an incorrect value for the mass of Saturn despite having the correct expression for the mass.

Question 4

This question was challenging for students with approximately half of the students being awarded full marks. Most students were able to answer Parts (a) and (b) successfully; however, those that did not gain full marks were mostly challenged by Part (c) – with the common error being that they did not include the direction of the magnetic field.

The more successful responses commonly:

* clearly stated that the magnetic field was directed out of the plane of the page at point A in (a)
* sketched the magnetic field around the conductor in (a)
* correctly showed the substitution of numerical values in (b)
* correctly stated the numerical value of $\frac{μ\_{o}}{2π}$ in (b)
* calculated the magnitude of the magnetic field as $4.8×10^{-6} T$ in (b)
* showed the substation of numerical values in (c)
* stated that the angle between the direction of the current flowing through the conductor and the magnetic field was 90 degrees in (c)
* calculated the magnitude of the force on the conductor as $ 1.05×10^{-3}N$ in (c)
* stated that force acting on the conductor was directed upwards in (c).

The less successful responses commonly:

* did not include units for Parts (b) or (c)
* did not provide a direction for the force in (c)
* used an incorrect formula for the force in (c).

Question 5

Parts (a) to (c) of this question were routine and were answered very well by most students. Many students found Part (d) challenging as incorrect values for acceleration were used, incorrect speeds were used in the constant acceleration formulae, and many students did not interpret their calculated values. Many students were not awarded full marks in (e) as the explanations did not include sufficient detail.

The more successful responses commonly:

* showed the correct substitution of numerical values in Parts (a) and (b)
* stated the calculated quantities in (a) and (b) to a greater number of significant figures then rounded their answers to give the required values in the questions
* clearly showed the rearrangement and substitution of values in (c)
* used the formula $s=v\_{o}t+\frac{1}{2}at^{2}$ to calculate the vertical displacement of the tennis ball after 0.859 seconds in (d)
* correctly calculated the vertical displacement of the tennis ball after 0.859 seconds and interpreted the quantities correctly
* stated clearly that the tennis ball did not make it over the net in (d)
* clearly explained that a damaged ball will have a greater surface area or higher drag coefficient in (e)
* clearly explained that the greater surface area will result in more interactions with air particles to produce a greater drag force in (e).

The less successful responses commonly:

* did not show the correct substitution of numerical values in Parts (a) to (d)
* did not show the rearrangement in the calculation of 0.859 seconds
* used the initial horizontal speed instead of the initial vertical speed in (d)
* calculate the maximum height of the ball in (d)
* used + 9.80 instead of -9.80 in (d)
* did not state if the ball made it over the net in (d)
* did not use physics terminology in (e).

Question 6

This question proved to be challenging, with most students being awarded one mark. Most students were able to correctly state that the plane of polarisation was vertical, but struggled to show that the waves at point P were at maximum amplitude.

The more successful responses commonly:

* stated that the electromagnetic wave was vertically polarised in (a)
* correctly calculated the path difference between the two waves in (b)
* clearly showed that the path difference between the two waves was an integer multiple of the wavelength of the waves in (b)
* clearly stated that if the path difference is an integer multiple of the wavelength, then constructive interference occurs which results in a maximum amplitude in (b)

The less successful responses commonly:

* did not calculate the path difference between the two waves in (b)
* did not clearly link constructive interference and maximum amplitude in (b).

Question 7

This question was generally answered well, with most students being awarded six to eight marks for the entire question. The most challenging part of this question was Part (d). Most students were not able to clearly articulate the link between the potential difference and the radius of the circular path, and very few students stated clearly that the increased radius resulted in fewer crossings of the gap between the dees.

 The more successful responses commonly:

* converted MHz to Hz in (a)
* rearranged the formula correctly in (b) to give $m=\frac{TqB}{2π}$
* showed the correct substitution of numerical values in (b) and (c)
* calculated the energy in (c) as $7.18×10^{-11} J$
* included correct units in Parts (a) to (c)
* explained that increasing the potential difference across the gap results in the particle moving in a circular path with a higher radius in (d)
* explained that since the radius of the circular path of the particle increases, it crosses the gap fewer times in (d).

The less successful responses commonly:

* rearranged the formula incorrectly in (b)
* showed a calculation that was inconsistent with the substitution in (b)
* used the mass of an electron in the calculation in (c)
* attempted to answer (d) using a formula only
* did not include units in Parts (a) to (c).

Question 8

This question proved to be challenging as it included both a derivation and a Science as a Human Endeavour question. Most students were awarded full marks for (b), and some marks for (a) and (c). Derivations still appear to be difficult for students as they often appear to struggle with how to start the derivation. In general, derivations should start with a physics principle or equation that is known from the content, then further equations added as related to the context. Science as a Human Endeavour questions continue to be challenging, as many students just ‘copy and paste’ from the text rather than include their own reflections on the text. Approximately one quarter of all students were awarded full marks for the entire question.

The more successful responses commonly:

* justified the use of equation in the derivation in (a)
* showed rearrangement steps in the derivation in (a)
* showed the square root in (b)
* cubed the separation between the Sun and the Kepler space telescope in (b)
* calculated the period in (b) as $3.23×10^{7} s$
* clearly stated which SHE strand was discussed in (c)
* clearly linked the stated SHE strand to the article content in (c)
* provided a detailed elaboration of how the SHE strand related to the article content in (c).

The less successful responses commonly:

* did not use correct equations for the derivation in (a)
* did not show any rearrangement steps in (a)
* used 9.80 instead of $6.67×10^{-11} $in (b)
* only provided direct quotes from the text in (c).

Question 9

This question proved to be good at differentiating students. Most students were awarded at least two marks for this question, but an almost even spread from three to six marks. A small number of students were awarded full marks. Responses to Part (c) suggest a gap in science inquiry skills and using/interpreting data.

The more successful responses commonly:

* stated clearly that the force acting on the electron is perpendicular to the velocity of the electron in (a)
* explained that if the force is perpendicular to the velocity, then the electron undergoes centripetal acceleration
* substituted numerical values correctly in (b)
* calculated the radius of the circular path correctly as $1.88×10^{-3}m$ in (b)
* clearly explained the correction between the graph and the equation $r=\frac{mv}{qB}$
* stated that the gradient of the line is proportional to the mass of the particle in (c)
* stated that particle A has the greatest mass.

The less successful responses commonly:

* did not use appropriate physical terminology in (a)
* did not calculate the radius of the circular path correctly in (b)
* attempted to calculate the mass of the particle in (c)
* stated the correct answer for (c) but did not provide any justification or explanation.

Question 10

This question also proved to be good at differentiating the quality of student explanations. Most students were awarded one to three marks, with very few being awarded full marks. Approximately one third of all students were not awarded any marks. Students should approach longer explanatory questions as one mark per explanatory point. Here, there are four key points that students needed to address – the law of conservation of momentum; the change in momentum when the photon is reflected; the change in momentum of the solar sail; and the link between change in momentum and acceleration.

The more successful responses commonly:

* stated the law of conservation of momentum
* explained that when photons are reflected from the solar sail, they experience a change in momentum
* used the law of conservation of momentum to explain that the solar sail also experiences a change in momentum
* clearly linked the change in momentum to force using $F=\frac{Δp}{Δt}$
* clearly linked the force to acceleration using $a=\frac{F}{m}$.

The less successful responses commonly:

* did not use the law of conservation of momentum
* did not provide sufficient detail in their explanation
* did not use appropriate physics terminology.

Question 11

This question proved to be very challenging, with approximately half of all students being awarded zero marks. The better students utilised the diagram as much as possible and were rewarded for doing so. Most students did not include sufficient detail relating the energies of the emitted photons with the energy of the incident photon that caused fluorescence.

The more successful responses commonly:

* stated that fluorescence occurs when an electron is raised two or more energy levels
* explained that when the electron transitions downwards, it returns via several small transitions
* stated that each transition downwards results in a photon being emitted
* used the diagram to assist their explanation.

The less successful responses commonly:

* did not use the diagram
* did not state explicitly that electrons need to transition upwards first
* did not explain that the electron transitions downwards via multiple energy levels
* did not use appropriate physics terminology.

Question 12

This question was answered generally well, with approximately two thirds of students achieving full marks. Many students found (c) challenging, particularly in identifying the correct frame of reference. Students need to have a clear understanding of reference frames, and how to determine reference frames, to answer questions like this successfully.

The more successful responses commonly:

* clearly showed the values of the speed of light values cancelling out in (a)
* squared 0.9956 *c* in (a)
* calculated the relativistic momentum in (b) as $5.32×10^{-18} kgms^{-1}$
* clearly articulated the frames of reference in (c)
* calculated the time in (c) as $1.277×10^{7} s$.

The less successful responses commonly:

* did not square 0.9956 *c* in (a)
* calculated the momentum (using $p=mv$ ) rather than the relativistic momentum (using $p=γm\_{0}v$) in (b)
* substituted 0.9956 as the speed rather than 0.9956 *c* in (b)
* incorrectly rearranged $t=γt\_{0}$ in (c).

Question 13

This question was generally answered well. The most common errors in the question were in determining the energy of the photon and converting the energy to Joules. Many students were awarded full marks for this question.

The more successful responses commonly:

* correctly calculated the energy of the photons in eV in (a)
* correctly converted eV to Joules in (a)
* correctly rearranged for frequency in (a)
* calculated the frequency in (a) as $3.08×10^{15} Hz$
* showed the substitution of all numerical values
* indicated that the photon was in the ultraviolet region of the spectrum in (b).

The less successful responses commonly:

* did not calculate the photon energy correctly in eV in (a)
* did not convert eV to Joules correctly in (a).

Question 14

This question was generally answered well. The students who were not awarded full marks typically lost marks in (b) through not justifying why the separation between the bands decreases.

The more successful responses commonly:

* rearranged $∆y=\frac{λL}{d}$ correctly to make $λ$ the subject in (a)
* showed the numerical calculation of the wavelength in (a)
* stated that the separation between the adjacent bright fringes would decrease in (b)
* provided a strong explanation for (b). Many students used the formula or an inverse proportionality relationship to justify that the fringe separation would decrease.

The less successful responses commonly:

* did not rearrange$ ∆y=\frac{λL}{d}$ correctly to $λ=\frac{d∆y}{L}$ in (a).
* included all scale factors in calculations in (a).
* did not provide sufficient justification for the separation between adjacent bright fringes decreasing.

Question 15

This question was good in differentiating students. Approximately one quarter of students were awarded full marks for this question. Many students found calculating the distance in (d) difficult, with many students using the acceleration in (b) or the acceleration due to gravity in the calculation. Students often find transferring the constant acceleration formulas in Topic 1 into new contexts found in Topic 2 challenging – care must be taken to identify why and how they can be used effectively.

The more successful responses commonly:

* showed the conversion from 4.00 cm to m in part (a)
* stated explicitly that the initial vertical speed was 0 ms-1 in (c)
* showed the correct rearrangement (either with symbols or numerical values) in (c)
* stated that there was no horizontal acceleration in (d)
* calculated a horizontal distance of $0.134 m$ in (d).

The less successful responses commonly:

* did not show the correct calculation in (a) and (b) but still stated that the quantities were equal to the values stated in the question
* did not state that the initial vertical speed was 0 ms-1
* used a horizontal acceleration of 56 ms-2 in (d).

Question 16

This question proved to be challenging for students. Many students were not able to sketch the X-ray spectrum effectively – if the potential difference across the tube is decreased, then the maximum frequency deceases, the intensity decreases, and the characteristic peaks remain at the same frequency. Many students appeared to have difficulty calculating the potential difference – many students with the correct expression calculated a maximum frequency due to how the data was entered into their calculator.

The more successful responses commonly:

* stated that attenuation is a reduction in energy/intensity of x-rays in (a)
* stated that bone had a greater density or higher atomic number than muscle in (a)
* stated that the bone would absorb more x-rays than muscle, or that there would be less penetration of x-rays in bone than in muscle in (a)
* calculated a potential difference of $7.13×10^{4} V$ in (b)
* stated explicitly that the maximum frequency of the x-ray spectrum was approximately $17.2×10^{18} Hz$
* sketched characteristic peaks at the same frequency as the spectrum in the question in (c)
* sketched a spectrum with a lower maximum frequency in (c)
* sketched the same general shape of the spectrum in (c).

The less successful responses commonly:

* described attenuation without discussing the bone or muscle in (a)
* did not state explicitly that the bone has a higher density than muscle in (a)
* did not include the scale factors in the calculation of the potential difference across the X-ray tube in (b)
* did not rearrange the formula for potential difference correctly in (b)
* did not show a reduction in intensity of the spectrum in (c)
* sketched the X-ray spectrum if the potential difference was increased in (c)
* did not include a lower maximum frequency in the X-ray spectrum in (c).

Question 17

This question was quite challenging for students. Most students were awarded marks for the questions, but typically lost marks in the parts that required a good understanding of experimental skills. Many students did not identify the horizontal intercept as the threshold frequency for the metal and did not understand the general relationship between frequency and maximum kinetic energy.

The more successful responses commonly:

* stated that the graph contained evidence of random error in (a)(i)
* described that errors may have been the result of incorrect data recording, variations in intensity, or irregularities in the metal in (a)(ii)
* rearranged and substituted correctly in (b)(i)
* used the threshold frequency (horizontal intercept) from the graph to determine the work function in (b)(i)
* calculated a voltage of $2.91 V$ in (b)(ii)
* sketched a line of best fit with a lower horizontal intercept in (c)
* sketched a line of best fit with the same gradient in (c).

The less successful responses commonly:

* stated that the line of best fit not passing through the origin was evidence of a systematic error in (a)(i)
* did not give reasonable suggestions for the cause of error in (a)(i) – e.g. ‘experiment not conducted in a vacuum’
* attempted to use points on the graph to calculate the work function in (b)(i)
* attempted to extrapolate the graph to determine the stopping voltage in (b)(ii)
* sketched lines with different gradients in (c)
* sketched lines that passed through the origin in (c).

Question 18

This question proved to be very challenging for students and highlighted a number of misconceptions. Many students did not appear to be able to articulate Lenz’s Law and did not appear to have a problem-solving strategy for determining the direction of the induced current. Students need to identify if the magnetic flux is decreasing or increasing, determine the direction of the magnetic field needed to oppose the change in flux, then determine the current that produces a field in this direction. Many students also calculated the number of magnetic field lines in the diagram – these are a qualitative representation of magnetic fields only. Many students also confused the use Tesla (T) with Tera (T) as a prefix for numerical quantities – many students incorrectly used 1012 scale factors in their calculations.

The more successful responses commonly:

* stated Lenz’s Law explicitly in (a)
* described the change in magnetic flux through the loop as the loop moved in (a)
* stated that the magnetic flux through the loop was decreasing
* stated the direction of the magnetic field through the loop in (a)
* calculated the change in magnetic flux in (b)
* substituted correctly in (b)
* calculated an emf of $0.0759 V$ in (b).

The less successful responses commonly:

* did not differentiate magnetic field and magnetic flux
* did not discuss the change in magnetic flux
* counted the number of magnetic field lines
* used an incorrect value for the number of loops
* used incorrect units for the induced emf.

Question 19

This question appeared to be very challenging for students, with approximately two-thirds of students being awarded zero marks. Students needed to first calculate the momentum of the electrons using the de Broglie wavelength, then use the momentum to calculate the speed of the electrons.

The more successful responses commonly:

* stated explicitly that the wavelength of the X-rays must be the same as the de Broglie wavelength of the electrons as the patterns are identical
* correctly calculated the momentum of the electron, using the de Broglie wavelength of the electron
* correctly calculated the speed of the electron, using the momentum of the electron
* calculated a speed of $5.87×10^{6} ms^{-1}.$

The less successful responses commonly:

* did not state that the wavelength of the X-rays must be the same as the de Broglie wavelength of the electrons
* calculated the energy of the X-ray photons
* attempted to determine the speed using the equation for kinetic energy
* did not use the mass of the electron in the calculations
* did not include units for speed.

Question 20

This question was good at differentiating students. Most students were able to answer (a) correctly but struggled to achieve full marks for (b). Students need to ensure that they are able to sketch electric field vectors correctly – including labels and the appropriate direction. Many students also did not appear to notice that an equilateral triangle was produced, and instead they attempted to calculate the net electric field algebraically. Many students also attempted to use cosine or sine rules – these should be avoided as they are outside the scope of the course and are often written incorrectly, giving erroneous answers.

The more successful responses commonly:

* showed the correct substitution in (a)
* correctly calculated the electric field due to charge *qA* in (b)
* showed all working for the calculation of the electric field due to charge *qA* at point P in (b)
* included labels on the vector diagram in (b)
* showed a correct vector addition in (b)
* clearly stated that the vector addition produced an equilateral triangle in (b)
* stated the net electric field was $1.26×10^{6} NC^{-1}$.

The less successful responses commonly:

* did not square the separation between the charge *qB* and point P in (a)
* did not substitute correct numerical values in (a)
* incorrectly calculated the electric field due to charge *qB* at point P in (b)
* did not include arrow heads on the vectors in (b)
* did not perform the vector addition correctly
* did not state explicitly that an equilateral triangle was formed from the vector addition in (b)
* did not include units for the net electric field at point P.

Question 21

This question was generally answered well with approximately half of the students achieving full marks. Many students did not achieve full marks as incorrect particle masses were used in (a) or students forgot to double the mass to take both particles into account. Part (b) was generally answered well, except some students did not appear to read in the question that the total number and types of quarks was the same before and after the interaction.

The more successful responses commonly:

* clearly showed that the masses of the proton and the anti-proton were included in the calculation of the energy in (a)
* calculated an energy of $3.01×10^{-10} J $in (a)
* showed clearly that the missing particle in the anti-proton was an anti-up quark in (b)
* showed clearly that the positive pion is composed of an up quark and an anti-down quark in (b)
* showed clearly that the neutral pion is composed of an up quark and an anti-up quark in (b)
* showed clearly that the negative pion is composed of a down quark and an anti-up quark in (b).

The less successful responses commonly:

* used the mass of an electron instead of the mass of a proton in (a)
* did not include the masses of both particles when calculating the energy in (a)
* did not square the speed of light in (a)
* used quarks and anti-quarks that were not included in the question in (b).

Question 22

This question was very challenging, with approximately two-thirds of students being awarded zero marks. Many students did not appear to understand what the question was asking, and considered each of the lines A, B, C, and D to be electron energy-levels, rather than the lines produced from a light source passing through a diffraction grating.

The more successful responses commonly:

* stated clearly that the transition from n = 3 to n = 2 causes a photon to be emitted with the lowest energy
* clearly stated that the lowest energy photon has the highest wavelength
* clearly stated that the highest wavelength corresponds to greater diffraction
* used the formula mλ = dsinθ to justify that the higher wavelength diffracts at a larger angle
* clearly stated D as the correct answer.

The less successful responses commonly:

* did not clearly explain the lowest energy corresponds to the highest wavelength
* did not justify why the highest wavelength corresponded to the greater diffraction angle
* stated two or more points as the final answer.