2022 Physics Subject Assessment Advice

Overview

Subject assessment advice, based on the 2022 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

Teachers can improve the moderation process and the online process by:

* ensuring that they are making decisions based on the current subject outline and the current performance standards when assessing their students’ work
* providing some evidence to support the grade awarded in tasks, such as a rubric, marking on a SAT or annotations on the student work.

Assessment Type 1: Investigations Folio

Assessment design criteria to be used for this assessment type are focussed in Investigation, Analysis and Evaluation with Knowledge and Application also forming a key part.

Teachers can elicit more successful responses by:

* including at least one opportunity in the practical investigations for students to deconstruct a problem for which the outcome is uncertain. The students should then design a method to investigate one aspect of this problem
* making it clear to the students that the Science as a Human Endeavour Report should be based on a contemporary focus and include clear links to some of the elaborations within the SHE concepts and some Stage 2 Physics concepts.

The more successful responses commonly:

* included at least one detailed deconstruction of an open-ended problem, making full use of the pages permitted with deep consideration shown about several possible lines of enquiry, the relevant physics concepts, possible variables and equipment that could be involved (IAE1)
* included an organiser, like a mind-map, lotus map or table to enhance the evidence of the decision-making process and included detailed justification about the key decisions made regarding the independent and dependent variables selected, the factors to be held constant and the equipment selected to collect the data (IAE1)
* included a deconstruction or design that contained a table of factors to control with the headings ‘how controlled’ and ‘why controlled’ or similar. Relevant physics concepts were applied in the table to justify the ‘why’ (IAE1)
* included a proposed data table that included the headings for the measurements of the independent and dependent variables that could be recorded and the intended number of repeats, units and expected calculations (IAE1, IAE2)
* made a clear distinction between where the maximum four A4 pages of Deconstruction ended and the maximum 1500 word Report on the investigation started (KA4)
* proposed a hypothesis that made a clear and justified prediction about how an increase or decrease in the independent variable would affect the dependent variable, often including a discussion about proportionality (IAE1)
* included a detailed list of materials and equipment used (IAE1)
* identified safety issues and described how to minimise them (IAE1)
* contained a clear, logical, detailed and justified procedure with a clearly labelled diagram or photo of the apparatus. In some cases, there was evidence of trials being used by the student to make key decisions about the method selected during the design or deconstruction phase (IAE1)
* used repeated trials and included all raw data in tabular format with appropriate headings, units and significant figures (IAE2)
* included a suitable graph in at least one of the investigations, with a line of best fit extrapolated back to the axes 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 to enable a justified conclusion about whether the relationship between the variables showed proportionality (IAE2, IAE3, IAE4)
* 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 effected 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)
* clearly and correctly linked systematic error to accuracy and random error to precision and demonstrated a clear understanding of these links and how they related to their data sets (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, coherently 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)
* had a Science as a Human Endeavour investigation with a contemporary focus such as a recent development in science, 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 clearly in the introduction and the report described each concept separately and in depth, making clear links to some of the elaborations within the SHE concept to demonstrate a deep understanding of the interaction between science and society. The Stage 2 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:

* were limited by heavily scaffolded practical reports that involved students filling in responses to scripted sections, like ‘state two errors and two improvements’, rather than presenting evidence of the student’s own ability to deconstruct, design and analyse an investigation (IAE1)
* consisted of a brief deconstruction that made only a basic attempt to identify possible variables and factors to control with minimal justification about the key decisions made regarding the selected variables, equipment to use and steps in the method (IAE1)
* confined the deconstruction to an 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)
* contained reports with very lengthy introductions that explained a lot of background physics, such as the explanation of two slit interference and the derivation of the equation, making it difficult to provide a deep analysis of the results without exceeding the word count (IAE1)
* consisted of a folio with investigations that only had a known outcome, such as the e/m electron ratio from the Teltron tube, the value of the absolute refractive index of Perspex or the value of Planck’s constant, limiting the opportunity for a genuine deconstruction anywhere in the Folio (IAE1)
* contained Investigations from the Stage 1 course, such as Snell’s Law or conservation of momentum in one dimension (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)
* included tables of results that used significant figures inconsistently or lacked clear headings and units (IAE2)
* 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)
* only used tabulated data, rather than a suitable graph, with minimal analysis of how the results linked to the investigation (IAE2)
* contained graphs that did not have axis labels or units or presented a ‘join-the-dots’ graph or used a trendline that was linear when a curve was more suitable for the data points present (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 trends in the data (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 affected by random and systematic errors (IAE3, IAE4)
* were limited to very broad statements such as “random errors impacted the precision of the practical”, rather than explaining how a specific error would affect the data (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 or explain the interaction between science and society (KA1, KA2, KA4)
* produced a Science as a Human Endeavour report that failed to even identify the Science as a Human Endeavour concept being explored (KA3)
* were based on 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 rather than an unsuitable focus, such as the historical development of an idea or piece of technology or invention, or an Issues Investigation about nuclear fission reactors (KA3).

Operational Advice

If students present their responses in oral or multimodal form, 6 minutes is the equivalent of 1000 words. Students should not speed-up the recording of their videos excessively in an attempt to condense more content into the maximum time limit.

From 2023, if a video is flagged by moderators as impacted by speed, schools will be requested to provide a transcript and moderators will be advised to moderate based on the evidence in the transcript, only considering evidence up to the maximum word limit.

If the speed of the recording makes the speech incomprehensible, it affects the accuracy of transcriptions and it also impacts the ability of moderators to find evidence of student achievement against the performance standards.

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.

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 and questions with a wide range of difficulties and instructions such as: state, describe, determine, calculate, draw, derive, show, explain, (KA1, KA2, KA3, KA4).

The more successful responses commonly:

* consisted of tasks that were modelled on past examinations with a good balance of questions that required the use of formulae and those that needed a description or explanation (KA1, KA2, KA3, KA4)
* 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).

The less successful responses commonly:

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

External Assessment

Assessment Type 3: Examination

General

* students need to ensure that they show all appropriate substitutions, conversions, and rearrangements in their working. Many students did were not awarded full marks as they did not show all appropriate working in their responses. If students just show a calculated quantity, then it is likely that they will only be awarded a single mark out of what might be a two, three, or four-mark question
* questions that require students to 'show' a quantity require all appropriate working to be shown, particularly if conversions are involved. If the student has not shown these workings in their response, then they have not shown that the calculated quantity required for - the question
* students should also use appropriate conventions. For example, many students wrote expressions like  rather than 
* significant figures continue to be an issue for students. Students should express their final calculated value to the lowest number of significant figures used in any of the values used in their calculation
* many student responses suggested that very little experimental work was completed or very little practise in contextual problem-solving. Students should be familiar with the Science Inquiry Skills as described in the subject outline.

Question 1

This question was generally answered well. Projectile motion questions are routine and should be familiar to all students. Part (a) required students to correctly resolve the initial speed in vertical and horizontal components. Responses to (b) were quite varied – the simplest method was recognising that the skier has a vertical speed of zero at the maximum height, and then use a constant acceleration formula to determine the time taken to reach the maximum height. Calculating the horizontal distance travelled by a projectile still proves to be difficult, with many students neglecting to double the time from (b) to calculate the total time of flight. A significant minority also incorrectly attempted to use the acceleration due to gravity to determine the horizontal distance travelled.

The more successful responses commonly:

* showed correct substitution and calculation for the vertical and horizontal components of the initial speed in (a)
* clearly stated (either in words or mathematically) that the vertical speed at the maximum height was zero for (b)
* clearly showed that the total time of flight in (c) was 0.860 s.

Question 2

This question was mostly answered correctly, with most students being awarded full marks for part (a) and at least one mark for (b). A small number of students did not square the distance between the two stars when calculating the gravitational force between Wurren and Zeta Phoenecis Ab. A large percentage of the students that attempted part (b) did not clearly link the gravitational forces explicitly to Newton's third law. Many students stated Newton's third law as 'every action has an equal and opposite reaction' – this does not provide the detail needed at Stage 2.

The more successful responses commonly:

* used the gravitational force equation correctly in (a)
* clearly explained that the gravitational forces between Wurren and Zeta Phoenicis Ab were equal in magnitude and opposite in direction in (b)
* stated Newton's third law explicitly in (b)
* clearly stated Newton's third law in terms of forces or interactions between objects with mass in (b).

Question 3

This question proved to be excellent in differentiating students in terms of their understanding of the Standard Model. Most students were able to calculate the electric force between the two protons, but a large number of students incorrectly calculated the gravitational force or used the correct formula for the electric force but substituted mass values instead of charge values. Many students neglected to square the distance between the protons giving an incorrect value for the electric force. Unfortunately, most students were not able to state the gauge boson for the electromagnetic force in (a)(ii). Most students were also able state that the quark composition of a proton is uud, but only about half of the students were able to provide a correct reason for their choice in (b).

The more successful responses commonly:

* used the electric force equation correctly in (a)
* substituted correct values for the charge of a proton in (a)
* stated that the gauge boson of the electromagnetic force is the photon in (a)(ii)
* stated clearly that the quark composition of a proton is uud in (b)
* stated explicitly the charge of an up quarks and down quark in (b)
* showed that the sum of the charges of two up quarks and a down quark is equal to the charge of a proton.

Question 4

This question elicited mixed responses from students. Some of the more common errors in (a) were forgetting to add the radius of the Earth to the altitude to find the orbital radius, and assuming that the orbital period of the GPS satellite was 24 hours, and neglecting to convert 20,200 km to m. Part (b) was answered correctly in two different ways – either using the result for (a) and the equation relating period to velocity, or the mathematical formula for Kepler's third law.

The more successful responses commonly:

* correctly converted 20,200 km to m
* added the radius of the Earth to the altitude to find the orbital radius
* showed all substitutions and working.

Question 5

This question was generally answered well. Most students were able to correctly indicate that Mercury had a higher orbital speed at any point on its orbit that was closer to the Sun. Students were less successful in part (b). Many students did not use Kepler's second law to justify the position indicated in (a) – it is important that students respond to the question in the way that is stated within the question. Many of the students who attempted the question using Kepler's second law did not provide sufficient detail when answering the question. However, there were many excellent responses, particularly those that used the diagram to aid their explanation.

The more successful responses commonly:

* stated Kepler's second law explicitly
* stated that equal areas swept in equal time intervals meant that larger distances along the orbit were travelled when Mercury was closer to the Sun
* clearly linked the distance travelled and equal time intervals to the speed of Mercury.

Question 6

This question was answered well. Most students were able to use the wave equation correctly and recognised that 206 MHz need to be converted to Hz. Part (b) was a little more challenging. Many students were able to state that the oscillating electrons produced an oscillating electric field, but fewer did not link either the oscillating electrons or electric fields to an oscillating magnetic field. Many students also did not use appropriate terminology – students need to state electric and magnetic fields rather than electric and magnetic waves.

The more successful responses commonly:

* converted MHz to Hz in (a)
* show the rearrangement and substitution of values into the wave equation in (a)
* explained that oscillating electrons produce an oscillating electric field in (b)
* explained that oscillating electric fields produce magnetic fields oscillating perpendicular to the electric field
* explained that the production of mutually perpendicular electric and magnetic fields produces a self-propagating electromagnetic wave.

Question 7

This question showed that many students do not have a good grasp of data analysis in the context of the photoelectric effect. Most students were able to draw an appropriate line of best fit in (a). Unfortunately, there were some students that did not have approximately even scatter of data above and below their line or produced a line with a gradient that was too steep. In part (b) many students did not appear to recognise that the vertical intercept of the line of best fit gives the work function of the surface. Further, many students stated the work function as a negative value – the work function is a measure of energy and is a positive value. Similarly, many students did not appear to recognise that the horizontal intercept is the threshold frequency of the surface. Part (c) was generally answered poorly. Students did not place enough emphasis on the need for a minimum energy to release electrons from the surface and did not strongly link the energy required to release the electron and the frequency of the photon that provides the energy.

The more successful responses commonly:

* produced a line of best fit that was linear and had minimal and even scatter of data about the line in (a)
* used the vertical intercept to state the work function in (b)
* use the horizontal intercept to state the threshold frequency in (b)
* explained clearly that electrons were bound to the surface by a minimum energy (work function) in (c)
* explained that the energy to release electrons is provided by a single photon in (c)
* explained that since the energy of a photon is proportional to the frequency of the photon, there is also a minimum frequency of light that released electrons from the surface in (c).

Question 8

This question was generally answered well. Part (a)(i) was fairly straightforward – students needed to substitute values from the question to give the spacing between adjacent fringes that was stated in the question. Part (a)(ii) was also answered well – most students recognised that the value calculated in (a)(i) gives the separation between adjacent fringes and not the width of the fringes. Part (b) was a little more challenging. Most students were awarded one or two marks for this question, but the best responses provided detail on the light emerging from both slits, the path difference between rays, and linked constructive interference to bright fringes. Alternatively, some responses discussed the production of bright fringes as the result of two waves arriving at the screen in phase. Part (c) was generally answered well. However, some students did not read the question carefully enough and did not use the separation of slits in the diffraction grating in their working. Some students were not awarded full marks as they did not substitute  or calculated the value of but did not calculate .

The more successful responses commonly:

* showed the substitution explicitly in (a)
* showed the conversion to mm explicitly in (a)
* explained that light rays from both slits form a bright fringe on the screen if they have a path difference of an integer multiple of the wavelength in (b)
* explained that constructive interference of two waves corresponds to a bright fringe on the screen in (b)
* showed the rearrangement of the formula for the angular position
* substituted the correct value for *m*
* Calculated the angle.

Question 9

This question also proved to be excellent at differentiating student understanding. In part (a) many students were able to describe the effect of the magnetic field in the cyclotron on charged particles, did not relate this effect to the purpose of the magnetic field *in the cyclotron*. Part (b) was generally answered correctly. Unfortunately, many students were not awarded full marks as the rearrangement of the formula and the substitution of the values was not shown. Part (c) was able to elicit which students had a good understanding of energy transfer in the cyclotron. Many students attempted to use the formula for kinetic energy but there was not enough data to complete the calculation. Here, the energy transfer occurs through work done on the proton as it passes through potential difference between the dees. Most students that attempted part (d) were awarded marks, but few students were awarded full marks. Many students framed their answer using the formula for kinetic energy – this type of response does not demonstrate knowledge of how the cyclotron works. Students use physics concepts to explain their answers rather than pointing out that the formula does not contain potential difference.

The more successful responses commonly:

* stated that the magnetic field causes the proton to undergo circular motion within the dees back towards the gap between the dees in (a)
* state that the circular motion of the protons was to allow *many crossings* of the gap so that the energy of the protons increases in (a)
* showed the rearranged formula and substitution of values in (b)
* converted kV to V in (c)
* calculated the work done with each crossing using  and multiplied their answer by 500 in (c)
* explained that increasing the potential difference between the dees increases the kinetic energy and speed of the protons in (d)
* explained that the increasing the speed of the protons increases the radius of the circular path of the protons within the dee in (d)
* explained that the increased radius corresponds to fewer crossings between the gap, and so leaving the final kinetic energy the same in (d).

Question 10

This question was answered quite well. Part (a) was answered well – it was a straightforward substitution with no conversions. Some students substituted calculated an incorrect value by substituting the charge of an electron as . Similarly, part (b) was a simple substitution without any conversions. Part (c) was a little more challenging. Students were required to determine the momentum of the electron, then use this value to determine the de Broglie wavelength.

The more successful responses commonly:

* showed the correct substitution of values in (a)
* showed the correct substitution of values in (b)
* calculated the momentum of the electron explicitly in (c)
* showed the rearranged formula for the de Broglie wavelength in (c)
* substituted values correctly to determine the de Broglie wavelength in (c).

Question 11

This question elicited mixed responses from students. In part (a), students still appear to have some difficulty in drawing vectors. Here students needed to resolve the normal force into vertical and horizontal components – both vectors need to have arrows and have to be scaled appropriately to the normal force vector in the question. Most students were able to correctly identify 12o as the correct banking angle but did not give sufficient detail when linking the angle to the cyclist's *reliance on friction*.

The more successful responses commonly:

* had correctly sized and labelled vectors in (a)
* explained that 12o increases the cyclist's *reliance* on friction as the horizontal component of the normal force is *reduced*.

Question 12

This question also proved to be good at differentiating students. Part (a) should have been familiar for to students – the electric field between point charges is a well-established part of the course. Many students do not appear to understand the requirements for questions that require students to show a particular value, such as in part (b)(i). Here students needed to show both the substitution of values and the conversion of the charge to Coulombs in order to be awarded full marks. Part (b)(ii) was quite challenging for students. Students were required to use the electric field value in (b)(i), perform an additional calculation of the electric field, and finally use vector subtraction to determine the net electric field at P.

The more successful responses commonly:

* showed the correct shape of the electric field line in (a)
* showed the correct direction of the electric field lines in (a)
* showed the electric field lines emerging and intersecting perpendicularly from the charged particles in (a)
* showed that the electric field decreased with distance by increasing the separation of the field lines in (a)
* showed the conversion from  to C in (b)(i)
* correctly calculated the magnitude and direction of electric field at point P due to q1 at P
* stated explicitly that the net electric field at P is the vector sum of the electric fields due to both charges
* correctly calculated the net electric field at P using vector subtraction.

Question 13

This question elicited mixed responses. In part (a), students needed to use the information that was given in the question to complete the table. Most students were able to recognise that the decay did not contain any baryons (giving B = 0 for all particles). Many students were able to correctly state the charge of each particle, but some students did not recognise that the muonic lepton number of an anti-neutrino is . Part (b) required students to interpret the values obtained in the table in (a). If (a) was answered correctly, then students should recognise that the decay was possible charge, baryon number, and muonic lepton number were all conserved. Part (c) proved to be excellent for differentiating which students understood the science as a human endeavour key concepts. Here, students were not required to recognise the key concepts, but use the context to explain the key concept of *communication and collaboration*. Many students were able to explain *communication and collaboration* in general terms but did not relate their description to the context of the question.

The more successful responses commonly:

* stated the correct charge, baryon number, and muonic lepton number in the table in (a)
* interpreted the table in (a) correctly to state whether or not the decay was possible in (b)
* explained their answer to (b) using the conservation laws for charge, baryon number, and muonic lepton number
* stated a general meaning of *communication and collaboration* at the start of the response in (c)
* explained how *communication and collaboration* can involve sharing data for review and verification in (c)
* explained that *communication and collaboration* can involve using standard international conventions in (c)
* made an explicit link between *communication and collaboration* and the measured lifetimes of the kaon minus particles in (c).

Question 14

This question was generally answered well. Most students were able to determine the direction of the magnetic field due to the current flowing through a conductor and use the formula correctly to determine the magnitude of the magnetic field in part (a). Part (b) was a little more challenging, as many students were not awarded full marks as they did not clearly state that since the magnetic field at S was zero, the magnetic fields due to the currents in conductors 1 and 2 must be equal and opposite. Most students were able to perform the calculation of the current correctly.

The more successful responses commonly:

* drew an arrow directed towards the top of the page at S for the direction of the magnetic field in (a)(i)
* showed the substitution of values into the correct formula for the magnitude of the magnetic field in (a)(ii)
* stated explicitly that the magnetic fields due to each conductor were equal in magnitude and opposite in direction for (b)
* correctly rearranged and substituted values for the correct value for the current in conductor 2 in (b).

Question 15

This question elicited varied responses. In part (a) many students correctly used the formula for the for the force between two charged particles. Most students were quick to recognise that any of the values in the formulas cancelled out leaving a relatively simple calculation. Unfortunately, many students did not calculate the square of the separation giving an incorrect value for the ratio. Some students calculated the ratio of the electric field due to the hydrogen nucleus at each distance – this response gives the correct ratio but students need to justify why this particular calculation is being completed. Otherwise, the response does not communicate knowledge and understanding of physics concepts. Part (b)(i) was generally answered well, but some students did not convert *eV* to J to give an incorrect value for the frequency. Part (b)(ii) required students to remember which transitions between electron energy-levels correspond to different parts of the spectrum. Many students answered correctly, but others appeared to guess. Many students appeared to understand part (c) but did not provide sufficient detail in their response. Most students were able to recognise that the energy corresponded to the difference between the  and  state but did not explain that a photon would cause an electron transition from  to .

The more successful responses commonly:

* substituted values correctly to obtain a ratio of 16 in (a)
* converted *eV* to J in (b)(i)
* used the relationship between energy and frequency correctly to determine the frequency of the photon in (b)(i), and showed the substitution and rearrangement in (b)(i)
* stated UV for (b)(ii)
* showed that 12.09 *eV* corresponds to the energy difference between the  and  electron energy-levels in (c)
* Explained that a photon is absorbed by an electron as it transitions from  to  in (c).

Question 16

This question was also elicited mixed responses. In part (a) most students were able to correctly state the dependent variable in the investigation was the induced emf in the coil. Unfortunately, there were still a fair number of students that stated the independent variable instead. In part (b), students were able correctly state that the falling magnet produced a changing magnetic flux through the solenoid but did not relate the changing magnetic flux to an induced emf via Faraday's law. Similarly, in part (c) students were able to correctly state that increasing the height increases the speed of the magnet as it falls through the solenoid. However, students did not link the increased speed to a greater *rate of change of magnetic flux*, and therefore induced emf.

The more successful responses commonly:

* stated *induced* emf in the solenoid in (a).
* explained that the falling magnet produces a change in magnetic flux through the solenoid in (b)
* explained the induced emf using Faraday's law in (b)
* explained that increasing the height increases the speed of the magnet as it falls through the solenoid in (c)
* explained that the higher speed of the magnet corresponds to a greater rate of change of magnetic flux in (c)
* explained the increased rate of change of magnetic flux to increased emf using Faraday's law in (c).

Question 17

This question was also answered generally well by students. In part (a)(i), most students were able to identify the maximum frequency of the X-rays by reading directly off the graph. Some students misunderstood the question and stated the frequency that corresponded to the maximum intensity instead. Some students also forgot to include the scale factor  in their answer. Part (a)(ii) was fairly straightforward and should have been familiar to all students. Students were required to rearrange the formula and substitute values to obtain the potential difference. Part (b) was a little more challenging, as there appeared to by many students who did not understand attenuation as a reduction in the intensity of X-rays. In this case, the bones absorb more of the X-rays reducing the intensity more than the absorption due to muscle. Students need to state that the attenuation was due to bones having a higher density than muscle.

The more successful responses commonly:

* stated the maximum frequency from the graph using an appropriate scale factor in (a)(i)
* showed the rearrangement of the formula in (a)(ii)
* showed the substitution of values in the calculation of the potential difference in (a)(ii)
* described that bone has a higher density than muscle in (b)
* used the relative densities of bone and muscle to explain why there was greater attenuation in bone than in muscle.

Question 18

This question elicited mixed responses from students. Part (a)(i) was fairly straightforward – many students were able to obtain the correct answer even if other parts of the question were not attempted. Part (a)(ii) was more challenging. In order to obtain full marks students needed to show some steps in the rearrangement of the formula for the Lorentz factor, then substitute values correctly to obtain the speed stated in the question. Many students used technology to find the speed rather than showing appropriate working. Similarly, if students substituted the value of the speed into the Lorentz factor formula to obtain 2.10 they were not awarded full marks. In part (b) could have used either the length contraction formula, , or recognised that this equation is equivalent to .

The more successful responses commonly:

* stated explicitly the times measured in the frame of reference of the Earth and the frame of reference of the moving quasar in (a)(i)
* showed multiple steps in the rearrangement of the Lorentz factor for the speed in (a)(ii)
* showed correct substitution into the rearranged formula in (a)(ii)
* state the times or lengths for the appropriate reference frame in (b).

Question 19

This question proved to be fairly challenging for students. In part (a) many students were not able to perform the derivation of an unfamiliar formula, despite using the same physics principles that are covered within the course. Many students also did not attempt any part of (b) if they were not able to show the formula in (a). Questions like this should be continued as the derivation itself does not impact other parts of the question. Students that attempted part (b)(i) were generally successful as the question was simply substituting values into the formula in (a) and multiplying by the mass of the xenon ion. Few students were awarded full marks for part (b)(ii). Students were required to use the formula relating the force to change in momentum, remember to take the number of xenon ions into account, and finally use Newton's third law implicitly, and the mathematical form of Newton's second law to calculate the acceleration. Some students were able to calculate the force correctly, but often substituted an incorrect mass value to calculate the acceleration. Others did not use the time interval given in the question and substituted  instead.

The more successful responses commonly:

* stated explicitly that the work done on a xenon ion is equal to the *change in kinetic energy* of the xenon ion in (a)
* equated the formulas for kinetic energy of the xenon ion and work done on the xenon ion in (a)
* substituted the values correctly in (b)(i) to obtain the correct change in speed of the xenon ion in (b)(i)
* used the formula for momentum to give the correct value for the change in momentum of the xenon ion in (b)(i)
* showed clear steps in working to link the change in momentum to the force on the spacecraft in (b)(ii)
* substituted the mass of the spacecraft to determine the mass of the spacecraft and thruster in (b)(ii).

Question 20

This question was fairly challenging for students. Many students did not undertake the vector additional correctly, did not state the law of conservation of momentum explicitly, or did not relate their working back to the question itself. Students needed to recognise that the net change in momentum must be zero, therefore, the sum of the momenta of piece A and piece B must be equal and opposite to the momentum of piece C. Students also needed to recognise that since piece A and piece B both had a mass of 2*m* the momentum of each needed to be determined using the centre of the first and last image for each piece.

The more successful responses commonly:

* stated explicitly the law of conservation of momentum
* used the diagram to draw vectors showing the momenta of piece A and piece B
* used vector addition to determine the sum of the momenta of pieces A and B
* used the law of conservation of momentum and vector diagram to determine the next position for piece C.