Questions matter

A Level

Physics

7408/3BD

Report on the examination

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Question 1

01.1
Most students were able to gain at least one mark on this question, however very few were able to gain full marks. A significant minority did not appear familiar with the process of thermionic emission at all. Marks could be gained from the diagram or text. When drawing these diagrams students need to take care to label diagrams and make clear what lines are wires and which refer to the glass enclosure, as some diagrams were ambiguous.

Most students were aware that a filament needed to be heated. However, a small minority did not realise that that was achieved with a power supply, with some students heating the filament with a heater or other source of heat: this did not gain a mark. Most students realised that a potential difference was required to accelerate the electrons, although some did not explicitly indicate that the anode required a hole to allow the electrons to pass through. Those who drew the power supply the wrong way round or drew incomplete circuits with only one side of the filament attached to the power supply, could not access this mark.

Very few students realised that thermionic emission requires either a vacuum or a low pressure gas, with this mark being rarely awarded.
Only a few students fully attempted the question and provided values for the potential differences; of these, most did not give suitable values. Many thought the low pd accelerated the electrons while a high pd was required to heat the metal, while others attempted to use just one pd to both heat the filament and accelerate the electrons.

01.2-01.5
Students had to determine a value for the specific charge, using Thomson's original approach which involved measuring the deflection angle of the electron beam. It was not expected that all students would have seen Thomson's approach before; however, it was expected that students would be able to apply their knowledge of fields and their understanding of measuring the specific charge to this technique.

The question explicitly told students that in this determination of $\frac{e}{m}$ it was not appropriate to use the values of e and m from the formulae booklet, so the many attempts which did use these values scored 0 for the part of the question where these values were used. However, this did not prevent other parts from scoring.

Questions **01.2** to **01.4** were "show that" questions where students are expected to provide the equations used as they appear on the formulae sheet, a substitution, a rearrangement (if required) and the answer to at least one more significant figure that the approximate value given in the question. While most students appeared to follow this, some lost marks by missing out some of these steps, most commonly only quoting the answer as the approximate value given in the question.

Most students found **01.2** accessible and were able to gain full marks. **01.3** was reasonably accessible with around two thirds realising that they could use trigonometry with their previous answer to get the mark. **01.4** proved more challenging, with the most common approach being to use $ma = \frac{QV}{d}$ with the values from the formulae sheet, which scored zero. Unfortunately, most of those students did not realise they could use this approach in **01.5** where it provided the correct route to the answer. In **01.4** the correct approach was to use the horizontal motion to determine a time and then an equation of motion to determine the vertical acceleration. Of those that used this approach, around half correctly used $v_h = at$ with their answer to **01.3**. However, the other half used $v^2 = 2as$, either using $2.5\ \mathrm{cm}$ as s or estimating a value smaller than this, as they realised the beam did not reach the top plate. These students were awarded 1 mark. Very few were able to determine the specific charge using $ma = \frac{QV}{d}$ in **01.5**. Most students either used e and m from the formulae booklet or mixed up the accelerating pd with the pd across the plates. A small number of students attempted to use the vertical deflection with the magnetic field.

01.6

This question was a standard question, however less than half were able to score, with even fewer able to score both marks. Some answers referred to atoms rather than ions or referred to helium rather than hydrogen and could not gain both marks. Some answers did not use comparative terms, referring to the mass of the electron as small, rather than as having a much smaller mass than the hydrogen ion. The idea that the specific charge was much larger, or several orders of magnitude larger, rather than just larger, was necessary to gain the first mark, as this was the key point of the significance of the Thomson's result. Answers which referred to size rather than mass did not gain the second mark.

01.7

This question addresses the details of making the specific charge measurements and is common to most approaches. This was an AO3 question, which asked students to evaluate two techniques where all the relevant information was given in the question. This required students to realise the difference between the two techniques:

- adjusting the apparatus to place the spot from the electron beam on a line on the scale means that the uncertainty would be determined by the diameter of the spot and the precision with which the lines were made. (This is similar to timing a falling object between two lines, where the uncertainty in the distance is defined by how the lines were originally measured rather than half the distance between them.)
- setting the magnetic flux density instead would mean that the scale had to be used to read the angle and the uncertainty would be determined by half a scale division (and the diameter of the spot).

This proved very challenging, with only around a quarter of students gaining a mark. Most correct answers did not provide enough detail for 3 marks, with most answers not making a comment about both techniques.

Many students incorrectly thought that there was a difference in the number of measurements in the two techniques rather than the same measurements in a different order and were therefore unable to score marks. Another common incorrect answer was to refer to parallax error, which does not apply in this case, as the spot is appearing on the surface of the glass where the scale appears. Even if the spot appeared on the other surface to the scale, this would not be an acceptable answer since it would apply equally to both techniques.

Question 2

02.1

Many students were familiar with the ultraviolet catastrophe with around two thirds scoring one mark and around a third gaining two marks. However, only a small number were able to score full marks. While marks could be gained from a labelled graph or the written explanation, some points required some written description to clarify. Unlabelled graphs could not gain credit and were ignored.

Most students were able to draw the experimental curve with its peak and the theoretical prediction without a peak.

The next most common mark was for a description that, in the theoretical prediction, the intensity tended to infinity as wavelength tended to zero and that this was not matched by the experimental results. Answers referring to “tending to infinity at UV wavelengths” were condoned. However, a common misconception was that the intensity tended to infinity as the temperature was increased, rather than as wavelength tends to zero at all temperatures. As students were asked to plot a graph of intensity against wavelength, in order to gain the mark students had to refer to the intensity, rather than other quantities.

Few students stated that the experiment agreed with theory at long wavelengths, although some talked about them being similar at long wavelengths which was not enough to gain the mark. This mark could only be gained from the written description.
Only a very small number of students knew that the intensity dropped to zero below a certain wavelength (which was not predicted by theory). Most graphs intercepted the intensity axis, stopped before meeting either axis, or passed through the origin, rather than meeting the wavelength axis at a positive value.

02.2

While most students were familiar with the idea of quantisation, most answers failed to give enough detail for the mark, most commonly missing out the reference to energy being proportional to frequency or an equivalent. It was pleasing to see some students quote Planck’s original nhf.
Students who mixed up Planck’s and Einstein’s contribution and referred to photons or the photoelectric effect were not able to gain this mark.

Question 3

The levels of response question was generally more accessible than in previous years, with some excellent answers seen. Most students were able to make good progress with around 60% scoring at least 3 marks. The question still discriminated well. Many, but not all, students seemed familiar with the concepts.
This question brought together different experiments concerning the speed of light and asked students what the significance of these measurements was.

Most students were able to gain 3 marks by:

- stating that Newton's corpuscular theory predicted that light was faster in water than in air
- stating that Huygen's wave theory predicted that light was faster in air than in water
- commenting that Foucault's experiment demonstrated Newton was wrong or Huygen was correct.

Students were not expected to be familiar with the work of Foucault, with the relevant information being given in the question, but were expected to apply their knowledge of Newton and Huygen's work to realise its significance. Most students were able to do this.

Many students were able to go on to give some details about Maxwell's theory of electromagnetism, although most did not provide enough information to fully address this area. A minority of students did not mention the electromagnetic nature of Maxwell's theories and stated that he predicted the speed of light, rather than the speed of electromagnetic waves.

Many students were also able to go on to express the idea that Fizeau's measurement of the speed of light matching Maxwell's prediction for the speed of electromagnetic waves, suggested that light was an electromagnetic wave.
However, the vast majority of students did not realise the significance of Hertz's measurement of the speed of radio waves, incorrectly stating that this proved radio waves were electromagnetic. Hertz had already established the nature of radio waves as electromagnetic through his other experiments. His measurement confirmed that Maxwell had correctly predicted the speed of electromagnetic waves.

The following were commonly seen but did not gain credit, although their inclusion was not penalised but ignored:

- Repeating information from the question or formulae sheet (e.g. just quoting $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ and stating the names of ε_0 and μ_0 from formulae sheet, or repeating what Fizeau, Foucault and Hertz did).
- Giving details about how the experiments were done. The question said, "Do not include any experimental details in your answer."
- Referring to other experiments performed by others (e.g. Young's double slits) or by the scientists named in the question (e.g. Hertz's other experiments with radio waves).
- Giving more details of Newton's and Huygen's theories (e.g. how they explained refraction).

A small minority mixed up Einstein's photon model of light with Newton's corpuscular theory of light, with many incorrectly thinking Einstein lived prior to 1800. Other common misunderstandings were suggesting that some or all of these experiments or scientists thought that the speed of light was invariant and attempting to link them to relativity. While the concept of an invariant speed of light is consistent with and could be implied by Maxwell's formula, this was not a view that was expressed prior to Einstein's paper on special relativity.

Question 4

Students generally found the relativity calculations much more accessible than the relativity questions in previous years. While most students realised that **04.1** and **04.2** required an explicit numerical comparison, a minority did not provide this and were not able to gain the last mark in either question.

04.1

Most students were able to make some progress and gain some marks, with around a third achieving full marks and over half gaining at least 3 marks. The question gave a maximum time that must be experienced by the cargo, a speed of the spaceship and the distance to be travelled. The distance and time were in different reference frames, so students had to use a relativity calculation so that data in the same reference frame could be compared, and a $v = \frac{s}{t}$ calculation so that the same quantities could be compared. There were at least 7 possible comparisons of quantities: comparing speeds, distances in either reference frame or times in seconds or days in either reference frame.

The first mark was for students correctly identifying 1.4×10^{14} as l_0 or 10 days as t_0 and substituting into a relativity equation. This could also be gained by using the results of a $v = \frac{s}{t}$ calculation as l or t.

The second mark was carrying out a $v = \frac{s}{t}$ with their substituted values in the same references frame. As v was the same in both reference frames, only those who used $s = 1.4 \times 10^{14}$ and $t = 10$ (days) or 864000 (s) or who used v as the speed of light did not gain this mark for the use of $v = \frac{s}{t}$.

The third mark was for correctly completing a relativity and a $v = \frac{s}{t}$ calculation. If these were carried out in sequence, then one answer was required. However, students could also carry out two independent calculations, the results of which were compared with each other, in which case two answers were required.

The fourth answer was for a numerical comparison and a correct conclusion. Students who had made calculation or power of ten errors could gain this mark, but it was only awarded for correct physics, so answers mixing up t and t_0 or l and l_0 could not get this mark.

04.2

This question was the more accessible of the two relativity calculations, with over 40% scoring full marks and over two thirds gaining 3 out of 4. Most students correctly identified 200 as l or 210 as l_0 and were able to use the equation $l = l_0\sqrt{1 - \frac{v^2}{c^2}}$ successfully. However, a minority of students dropped the squares on the speeds or squared the speed of light but not 0.5. Sometimes this was just in their working but the calculation was correct, in which case they did not gain the first mark but did get the third, while in other cases the calculation also missed out the squares. Some students truncated the length of the cargo as 181 rather than rounding to 182 and did not gain the third mark.

A few students were able to successfully complete the calculation but did not realise the significance of the numbers and said that the cargo would not fit in the spaceship.

A small number of students did not know whether 200 (or 210) was l or l_0 and provided both calculations. This was regarded as a contradiction and so they were only able to score the first mark.

04.3

This question proved surprisingly challenging with just under 50% getting the mark. While most students can quote Einstein's postulate "the speed of light in free space is invariant" or "the speed of the light in free space is the same regardless of the speed of the observer or source," only around half could apply it to this context. The radio wave, as a form of electromagnetic wave, would have to be measured as travelling at c by all observers, including those on spaceship **B**.

The most common wrong answers were $0.80c$ (the spaceships' speeds added together, or the difference in speeds subtracted from c), and $0.20c$ (the difference between the spaceships' speeds, or the sum of the spaceships' speeds subtracted from c).

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.