A Level

Physics

7408/2

Report on the examination

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The paper had an overall increase in the mean mark compared to last year of nearly 10%. Section A was much more accessible than last year with the mean increased by over 10%, while the mean mark for section B increased by around 5%. The mean percentage mark of section A and section B were similar, whereas in previous years section B usually had a higher mean percentage mark. Most students generally coped well with the contextual questions but found some of the other questions more challenging. While most students were able to gain more marks, those around the E boundary saw only a small increase in their average mark.

Question 1

Question 1 was about determining nuclear radius, and addresses most specification points from section 3.8.1.5. Although all aspects of this question have been previously examined and the question was context free, this was the most challenging question on the paper with a mean mark of around a third of the total marks available.

1.1
In the first part of the question students were asked to estimate the radius of the gold nucleus using the distance of closest approach. This required the students to equate the alpha particle's electrostatic potential energy $\frac{Q_\alpha Q_{\mathrm{Au}}}{4\pi\varepsilon_0 r}$ with its kinetic energy converted into joules. As the formula for the electrostatic potential energy has to be deduced, this gained a mark if it was seen. A small number of students knew the approach but incorrectly used the mass number instead of the proton number when calculating the charge of the alpha or gold nucleus.

Many students seemed unfamiliar with this approach. Common incorrect approaches included using $R = R_0 A^{\frac{1}{3}}$, mixing up velocity v and potential V, and using $\frac{1}{2}mV^2 = E_K$ or squaring the radius so the kinetic energy is effectively equated to force rather than potential energy.

The most common mark gained was for converting the kinetic energy to joules, although some did not attempt this.

1.2
Students had to explain why their answer to question **1.1** was an estimate. Very few students provided two reasons and the majority were therefore limited to 1 mark. This required students to apply their knowledge of the comparison between the distance of closest approach and electron diffraction. Ideally students should express the idea that the distance of closest approach depends on the energy of the alpha particle, or only depends on the number of protons not the actual number of nucleons; however other ideas such as it being an upper limit, the recoil of the nucleus being ignored, or the alpha particle having a finite size were allowed, although in practice they have a much smaller effect. The idea that it was based on the distance of closest approach was given in the question and therefore did not gain a mark; however, a deduction from this, e.g. the alpha particle does not touch or hit the nucleus, was condoned.

Ignoring the strong nuclear force was condoned, as this is usually accepted as a reason why electron diffraction is the preferred method, although the question specifically asked about the estimate in 1.1, which is an order of magnitude too large for the range of the strong nuclear force.

Responses which referred to the non-spherical nucleus were not rewarded as this is not a significant factor in this experiment.

1.3

Many students seem unfamiliar with the intensity angle graph for electron diffraction, with many drawing single or double slit light diffraction patterns instead. The mark scheme for this series was was generous and focused on a central peak with a subsequent non-zero minimum. Some students did know that the first minimum was used but many did not; incorrect responses included the maxima, the gradient or the area under the graph.

1.4

Students were asked to show that the equation $R = R_0 A^{\frac{1}{3}}$ provided evidence for the constant density of nuclear material. While many students knew that the nucleus was spherical and were able to use the equation for the volume of a sphere, only a few of these could substitute the given equation for R into these formulae, then use it in the density equation and cancel the A's. Only a small number were then able to comment on the fact that all of the remaining terms in the equation were constant or did not depend on R. Since nuclear density being a constant was mentioned in the question, responses had to refer to the quantities rather than the equation itself being constant.

Question 2

Question 2 was about kinetic theory and was more accessible, with a mean mark of around 50%. Students found 2.1 and 2.3 to be most the challenging parts of the question.

2.1

Most students did not understand the use of the term "random motion" in kinetic theory. Many mixed up the concept with Brownian motion or the random nature of radioactive decay, comment that it is unpredicted, it is spontaneous, or it can't be affected by external forces. None of these gained marks. In order to gain marks here, students needed to define the word 'random' and not just refer to random direction and speed. While a range of speeds was accepted and should have been accessible, few talked about the speed or the magnitude of the velocity with most focussing only on the direction. The direction was more demanding where answers had to demonstrate the idea that there was no preferred direction, rather than just a range of directions. A very few clearly knew the derivation and used ideas like $\overline{c_x^2} = \overline{c_y^2} = \overline{c_z^2}$; this was rewarded, although centres should note that if symbols are used that are not defined in the questions, they should be defined in the answer.

2.2

Generally, students were able to state two of the other assumptions, although some students lacked detail in their responses, referring to the volume being negligible without stating whether they meant the volume of the particles or the gas. A common error was referring to identical particles, constant mass or constant temperature.

In this question, referring toa large number of particles was not accepted as this is only important in ensuring that the particle motion is random and was not therefore considered as another assumption.

2.3
This was a standard question about using kinetic theory to explain why a fixed mass of gas should expand when heated at constant pressure. Many students found this to be accessible, but some did not express their answer in terms of kinetic theory.

In similar questions students should be encouraged to pay attention to the “using” section. Only answers which address this aspect of the question are going to score. Similar questions could be asked with:

- using equation(s) of state / gas laws derived from experiment
- using kinetic theory
- using Newton’s laws

In this case the questions specified that the answer must use kinetic theory. There were two approaches possible: an argument based on the principles of kinetic theory referring to the change in momentum of particles when they collide with the wall, or by using the equation introduced in the stem of the question $pV = \frac{1}{3}Nmc_{\text{rms}}^2$. Approaches that used the equation had to give more information than merely quoting the equation. For the last mark, the following general principles were strictly insisted upon:

- when using symbols in their answer that are not defined in the question, students must define them, and
- when using an equation to deduce what happens to one quantity when another changes, quantities that are not changing must be explicitly identified as constant.

As is common in most years, students are very good at identifying which quantities are changing but are much less likely to state which quantities are constant. In this case, students had to name the quantities and state that they were constant. Very few students did this.

The idea that the gas pushes out on the walls and therefore it must expand was seen frequently and was rejected because an outward push on the walls defines pressure and does not require an expansion.

2.4
Most students found this question straightforward, with most able to score a mark. A few lost the mark due to rounding errors, adding 273 to the change in temperature or by mistakenly writing 1.35 instead of 1.035.

2.5
This was generally well answered and proved much more accessible that the earlier written parts of the question, despite being the only part of the question to address an unfamiliar context. Most students calculated the energy required to raise the temperature of 1 molecular mass of water by 50K and compared their answer to **question 2.4**, concluding that water vapour does not behave like an ideal gas.

However, any mass and temperature was possible and many possible routes were allowed, including determining a specific heat capacity based on the increase in kinetic energy of the molecules and comparing to $1400\ \mathrm{J\ kg^{-1}\ K^{-1}}$ or comparing differences in temperature or masses.

A small minority of students did not use the specific heat capacity for water vapour and used the value of liquid water.

Some students did not gain the last mark as there was no explicit comparison between quantities. Ideally, an answer should compare the values, state what those values mean and give a conclusion.

Question 3

Question 3 was about radioactive decay set in the context of a radioisotope thermoelectric generator used to power a Mars rover. This question was the most accessible on the paper with a mean mark of around two thirds of the total marks.

3.1
Most students were able to determine the initial mass of plutonium from the number of atoms.

3.2
The context of an RTG has been examined before and this 5 mark calculation was accessible, with the majority of students able to score some marks. The steps could be undertaken in any order with multiple different routes to the answer. This meant that most students were able to use at least some of the data in the question correctly and make some progress, while only the higher achieving students were able to gain full marks.

Marks were awarded for determining the initial activity, dividing an output power by the kinetic energy of the α to determine an activity correctly using the efficiency, using the decay equation for activities, number of nuclei, masses or powers, and for converting either the time to years or the decay constant to $\mathrm{yr^{-1}}$.

A common mistake was for students to use $E = mc^2$ and assume that all of the mass of the alpha or the plutonium was converted into energy. Another mistake was for students to mix up the number of undecayed nuclei N, in the equation $A = \lambda N$ with the nucleon number and multiply λ by 238.

3.3
This 4 mark calculation proved very accessible with about three quarters scoring at least 3 out of 4. The sublimation of carbon dioxide did not seem to pose a significant challenge to most students, with only a very small number missing out the latent heat of fusion of ice or including heating the melted water to $100\ ^{\circ}\mathrm{C}$ in their calculation.

Most students approached this by calculating the energy produced by the laser and comparing this to the heat required to raise the temperature of the ice, melt the ice and vaporise the ice. However, other approaches were possible, with some students calculating the time taken and comparing this with $3.0\ \mathrm{s}$, or calculating a mass that could be vapourised by the laser in $3.0\ \mathrm{s}$.

Again, a small minority of students did not get full marks because, after completing a correct calculation, they did not include an explicit comparison. Only a very small minority correctly completed the calculation and gave an incorrect comparison. Most of the marks lost were due to power of ten issues with the calculation.

Question 4

Question 4 examined gravitational fields and potentials for the moons of Saturn. The mean mark for this question was just under half of the total marks. While students found the later part challenging, part 2 was accessible but answers lacked detail, and some students struggled with interpreting the graph scale in part 3.

4.1

This question was accessible to most students with over half scoring at least 2 out 3. Common mistakes were: forgetting to add the radius of Saturn, cube the radius, use the square root to determine T, converting to seconds and then not converting back to years or assuming that the angular speed was the same for both moons. The easiest approach was to use $T^2 \propto r^3$ e.g. $\frac{T_1^2}{r_1^3} = \frac{T_2^2}{r_2^3}$, however determining the mass of Saturn from $T^2 = \frac{4\pi r^3}{GM}$ and then using this to determine the period of Enceladus was also a valid approach.

4.2

Most students correctly identified that the graph was linear, however, most of them did not fully explain the significance of this. To explain why the suggestion was correct required a statement that the gravitational field strength was equal to the gradient.

A minority of students answered this by referring to the small range of distances shown compared to the distance from Saturn. Again, to fully explain why this was important, they needed to link this to an equation. Most who followed this route did not do this.

4.3

Most students were able to realise that this was when the curved line was horizontal but significant numbers made mistakes reading the graph, either missing out the 10^8, writing 12.35 instead of 12.035 or failing to read to an appropriate number of significant figures for the range shown on the graph (e.g. 12.0).

4.4

This question was challenging, although over 60% gained at least 1 mark, only the best students were able to make more progress than this.

Students had to read off the potentials from the two lines at a distance of 12.08×10^8 m from Saturn and then subtract the values. Some students incorrectly attempted this at the end of the lines, rather than the value that was quoted.
Students could then get a mark for using their answer or the value quoted in the question into $V = -\frac{GM}{r}$, or by rearranging the equation to make M the subject. This was the most commonly awarded mark.
The least commonly awarded mark was for determining r, the distance from Titan, by subtracting the distance from Saturn from the distance between the centres of Titan and Saturn.

Question 5

This question again proved challenging with a mean mark just below half of the total, although it was set in the familiar context of a circuit that was used to charge and discharge a capacitor. The students found the calculations accessible but struggled with the definition of the dielectric constant and sketching the current–time graph for a charging capacitor.

5.1
Most students struggled to answer this question well, with only around third gaining the mark. Most scoring answers went beyond the specification with answers in terms of the ratio of permittivity to the permittivity of free space. Although this answer is not covered by the specification, it is correct and was accepted. Most answers that attempted this route confused the relativity permittivity with the permittivity and so were not able to access this mark. Students should again be reminded that if they use symbols not defined in the question, they must define them in the answer.

Very few were able to answer this question in terms that were on the specification e.g. for the same plates separated by the same distance the charge stored is 7 times larger with the dielectric than with air (or a vacuum). Most answers that attempted this either did not mention air or a vacuum or did not provide a comparison at all.

5.2
Most students were able to determine the time constant from the discharge graph. However, a small number of students confused the time constant with the half-life or misread the scale on the time axis. A very small minority attempted to use the gradient or the area under the graph.

5.3
Most students were able to successfully find the ratio of currents. However, while the approximate decrease in current in one half-life of 0.37 was accepted, students are expected to use e^{-1} instead.

5.4
This question proved challenging for many students, with only a very small number drawing a fully correct graph. Students did not have to draw a fully correct graph to gain full marks in this question.

While most students realised that the current decreases with time $\left(I = I_0 e^{-\frac{t}{RC}}\right)$ for a charging capacitor and so gained a mark, many incorrectly thought that the current increases $\left(I = I_0\left(1 - e^{-\frac{t}{RC}}\right)\right)$. However, a significant number of students drew neither graph, drawing either an exponentially increasing, linear or sinusoidal graph. A small but significant number of students drew a decreasing current that ended at a constant non-zero value and did not get this mark.

A further mark was available to those who realised that the current would be in the opposite direction when charging to discharging and therefore the milliammeter reading would be negative.

Most students did not appreciate that the extra resistor in the charging part of the circuit would double the total resistance and therefore halve the initial current and double the time constant. Some students did appreciate the time constant would double but very few correctly halved the initial current.

Question 6

Question 6 examined gravitational, electric and magnetic fields separately in the context of the plasma torus around Jupiter. While this context was unfamiliar, most students coped well with most contextual elements but struggled with the concept of the vector nature of electric fields. The mean mark was around 50% of the total marks.

6.1
Students found this question very accessible, with most following the prompting in the question to determine and compare the centripetal acceleration of the ion with the gravitational field strength at the ion's location. Most students remembered to include the comparison in this question, as they were comparing two calculated values.

However, this was not the only approach, with a wide variety of approaches seen for a minority of students. The most popular was comparing the speed for a gravitational orbit with the ion's speed and included comparing the value of G required with the value of G on the formulae sheet. All correct approaches were rewarded.

6.2
Drawing the direction of the magnetic field required to make the ion move in a circle proved challenging for many students, with less than a third gaining the mark. The question was a straightforward application of Fleming's left-hand rule. Allowances were made for the 3D nature of the diagram, so arrows which were not vertical but attempted to take into account the angle of the diagram were rewarded. The most common wrong answer was drawing the arrow towards the centre of the Jupiter. It is unclear whether this was due to incorrectly applying Fleming's left-hand rule, misreading the question, or mixing up magnetic and gravitational fields. A few students sketched the full magnetic field of Jupiter; provided one of the field lines was close to the ion and in the correct direction, this approach gained the mark.

Only a few students did not get the mark because they did not draw the arrow sufficiently close to the ion.

6.3
Around two thirds of students were able to calculate the required magnetic field strength, with only a few making power of ten mistakes. However, providing the unit of magnetic flux density in fundamental base units proved more challenging. Some just quoted the tesla, which was not accepted. There was evidence of both mixing up the units of magnetic flux density and magnetic flux, and thinking that coulombs rather than amperes was the relevant fundamental base unit.

6.4
Most students were able to determine the acceleration of the ion, although a minority of students mixed up the field and the potential.

6.5
This question was context free, yet proved challenging for students, with only around a quarter able to gain full marks. Students had to calculate the electric field at **P** for **X** and for **Y** and then combine them as vectors using either Pythagoras or trigonometry.

Common mistakes were: students calculating the force exerted by the charge on each other using coulombs law, determining the field at the location of the other charge rather than **P**, mixing up the field and the potential, and treating the field as a scalar and simply adding or subtracting the two electric fields.
Those students who treated the fields as scalars and who did the algebra before substituting in the values at the end, often scored 0 marks, because they did not write down either charge correctly, did not have a valid substitution into an electric field equation and did not combine the electric fields as vectors. Had they substituted earlier they could have gained 2 marks. This significantly lowered the mean mark for the question.

Section B
Students found questions 11, 14, 17, 28 and 30 to be very accessible with over two thirds getting these correct.

Students found the following questions more challenging:

15 Around a third of students answered this question correctly.
To answer this question, students must consider the magnitude and direction of the fields which would total to give zero. The magnitudes of the fields must be equal, so, since the magnitude of the charge of **Q** is larger than the magnitude of the charge of **q**, the point must be closer to **q**. The answer must be **C** or **D**. As electric field strength is a vector, when there are two charges the only way to get zero is for the fields to point in opposite directions. At any location between the two charges, the fields will point in the same direction, as it must point towards one and away from the other. The answer must be **A** or **D**.
Therefore, the answer must be **D**; it is closer to **q** and the fields are in opposite directions.
The most popular answer was **C**, showing students had an awareness of the magnitude of the charge but did not properly take into account the vector nature of electric field. This is

consistent with the responses to question **06.5** where students also struggled with the vector nature of electric fields.

20 This question was very challenging with only around one quarter correctly answering this question. This question relies on $mg = BIL$ and $m = \rho V = \frac{\rho \pi d^2 L}{4}$ giving $\frac{\rho \pi d^2 L g}{4} = BIL$. Therefore, since ρ, g and B are constants and L cancels, $I \propto d^2$, the new current required is $4I$. **C** was the most popular answer, suggesting that students only took into account the new dimension's effect on either the mass or the magnetic field but not both.

21 Just less than a third of students answered this question correctly. This question required students to realise that as the coil rotates through π radians, the magnetic flux first increases and then decreases. Thus, the emf changes sign and the mean induced emf is 0.

22 This question was very challenging with around one quarter of students answering it correctly. The correct answer was only the third most popular response.
As a conductor moves through a magnetic field, the induced emf is given by $\varepsilon = Blv$, however the students had to identify which distance was l. l is the distance that is perpendicular to both the velocity and the magnetic field. The magnetic field is vertical, so l cannot be $10\ \mathrm{cm}$; the velocity is in the same direction as $30\ \mathrm{cm}$, so l must be $5.0\ \mathrm{cm}$. The answer is therefore **D**. The most common answer was **B** which corresponded to $l = 30\ \mathrm{cm}$, the second most common answer was **C** corresponding to $l = 10\ \mathrm{cm}$.

23 This question also had the wrong answer as the most common choice, in this case **C**, with only around a third correctly identifying **A** as the correct answer. Students had to realise that $P = I_{\mathrm{rms}} V_{\mathrm{rms}} = \frac{5 \times 50}{2} = 125$ W. Thus, the efficiency is $\frac{100}{125} \times 100 = 80\%$. **C** comes from calculating the power from the peak voltages rather than the rms values.

25 Around a third of students were able to answer this question correctly. This uses the inverse square law for radiation, which gives $800d^2 = 600(d + 10)^2$, giving $d = 64\ \mathrm{cm}$.

27 Only around a third realised that in **D** the nucleus absorbs an electron from the inner electron shell leaving a gap for an electron to fall into, thus producing an excited electron. The others leave the nucleus in an excited state, rather than an electron.

31 The most popular answer to this question was **C**, with just over half thinking that any fission to the right of the peak will release energy. However, the nuclei with approximately half the nucleon number of the nuclei in region **Q** have a lower binding energy per nucleon and so would not release energy in fission. Only nuclei with a large nucleon number such as those found in region **R** will release energy when fissioning. Around a third got this question correct.

Mark Ranges and Award of Grades

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