Examiners' Report
Principal Examiner Feedback

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Introduction

This paper proved to be a fair test of student knowledge and understanding. It provided a high level of challenge as always, although there were a good number of more accessible marks that were widely scored. With the exception of Question 1, fully correct solutions were quite rare, particularly with the last two demanding questions, although several impressive attempts were seen that demonstrated impressive style and clarity of presentation.

It is clear that a good few of the students' completely unprepared for the exam, which is not surprising as the Covid situation will have limited preparation time. Nevertheless there are some very good students that can do well in this exam, if they are given the encouragement and support of a teacher - and there were several good examples throughout the paper where students communicated their ideas effectively and presented excellent solutions. These responses showed the paper behaved as expected in the main.

Some general comments about advice to students.

Successful students were able to use the early parts of a question to help with the later parts.

This was true for question 3, 4, 6 and 7, although it was really in question 7 that many students needed to be using part (b) in the final part. Many missed this and made no progress.

A key teaching point is to get students to understand how the early part of these questions can help with the later parts.

Students should also be aware of the usefulness of simplifying as they go through a problem. This is especially the case in a non- calculator exam. Such techniques as extraction of square factors from square roots and of cancelling fractions to make the arithmetic easier. There were cases in question 5 where the coefficient of $(Vt)^2$ was left as $\frac{45}{25}$ so the numbers when dealing with the discriminant were larger than they need be. This was also the case in question 7(d) where some students used the formula rather than factorise (ignoring the hint about 7, 24, 25). It would have been the case in question 2(b) also - but most students could not get that far through the question.

Students should be given the warning 'think hard before you expand brackets!' This was especially the case in question 3 when expanding tan $(\theta + 11)$ led to disaster and on parts (a) and (b) of question 7 where students who expanded everything usually made errors along the way with the algebra.

Good diagrams can be helpful. For example, question 5(a) , where a clear diagram showing relative positions of the two planes, together with information about the components of their velocities was generally accompanied by successful derivations. A good drawing, using a pair of compasses would have helped on question 7(c) and (d).

Reports on Individual Questions

Question 1

The opening question on differentiation saw good scoring for the majority of students with full marks being widely awarded and was by far the most successfully answered question on the paper. However, about a fifth of students did not see how to use logarithms to get started and invariably scored no marks. They presumably had not met logarithmic differentiation or did not know the derivation of $\mathrm{f}'\mathrm{e}^{\mathrm{f}(x)}$ from $\mathrm{e}^{\mathrm{f}(x)}$ or failed to connect such with the given function., with $x^2\mathrm{e}^{x^2-1}$ or something similar sometimes seen, a mistake that is quite poor for this paper.

Most chose to take natural logarithms of both sides and the subsequent application of the product rule was almost always correct. A small number lost accuracy marks by using logarithms to the base 10. Those that completed the differentiation correctly almost always proceeded to the required *x* coordinate of the stationary point, while a few incorrectly confused range and domain stating that

$\ln x = -\frac{1}{2}$ has no solution as $\ln(x) > 0$

Some worked out both coordinates, not having paid careful enough attention to the question.

Question 2

This question on vectors in a mechanics context proved to be difficult and although some were able to attain all five marks in part (a), significant scoring in part (b) was quite rare. The modal score was 5 marks, attained by 23%, which essentially was a fully correct part (a) with no correct work in (b). Less than 10% were able to score full marks.

In part (a), many students could not see a way to obtain the required vectors in terms of **p** and **q**. Those that put together a decent diagram usually found this to be beneficial. Students who could find the required vector expressions usually proceeded to the correct resultant force. However, many assumed that $\overrightarrow{OT}$ was equal to $\overrightarrow{PQ}$, not appreciating the directions are different, and many other similar misconceptions were made.

Success was very limited in part (b) although some were able to find the length of *q* relative to *p*.The majority knew to use "**F**=*m***a**" but few knew how to approach this as a modulus equation. Most could not see a way of translating the problem into one involving a single variable. The few that did identify that the cosine rule or an equivalent method was required often got beyond the first mark. Some attempts could only establish that the modulus of **R** was 39. Others assumed that **p** and **q** were perpendicular and merely attempted the magnitude of *a***p** + *b***q**. Some treated **p** and **q** as parallel and were not working with the moduli. It was common to see

$|\mathbf{R}| = (-)27|\mathbf{p}| + 21|\mathbf{q}|$ or that $|\mathbf{R}|$ could be found from $\sqrt{27^2|\mathbf{p}|^2 + 21^2|\mathbf{q}|^2}$

A few attempts at resolving were seen but were rarely successful with only a few able to express **q** in terms of **p** using unit perpendicular vectors. If they managed this successfully they went on to complete the question correclty.

Question 3

This trigonometric equation question saw good scoring in part (a) with full marks widely awarded. Progress was fairly limited in part (b) however, with most students unable to pick up on the clue that part (a) provided. The modal mark, by some way, was 4 out of 10, scored by 44%, being the three marks in (a) and first M in (b). Marks of 3 (from part (a)) and full mark were the next most common scores (11%).

In part (a) most were able to express tan in terms of sin and cos and use the correct compound angle formulae. Invariably correct completion was achieved with only a handful of slips seen which were usually sign errors. Only 1% scored no marks at all for the question, with 6% scoring fewer than 3.

A wide range of strategies were attempted in part (b) with varying degrees of success. The first mark was commonly scored, usually by correct application of $\sec^2 x = 1 + \tan x$. However, most were unable to deduce that rearrangement of the equation could then allow the double angle formula for tan to be used followed by the result from part (a). Most success was seen via Way 2 where many students were able to use the double angle formulae for sin and cos to make progress but the significance of part (a) was not appreciated by many. Some did achieve a correct equation in θ and if so they generally applied $+k180°$ fully to achieve all six solutions, though some missed one or more out. Some attempts used Way 3 reaching both required linear equations in tan, though some did overlook the 1 - tan (θ +11) = 0 partial solution, and then proceeding to find the correct solutions for the first equation. However, without a calculator to deal with the arctan of the surd it proved almost impossible to generate any solutions for the second equation. A few students with correct equations in θ succumbed to arithmetic errors. The S mark was scored by many who obtained at least 4 solutions, the method to find extra solutions being apparent in the work.

The major problem for many students in part (b) was the immediate desire to try and expand the tan terns using compound angles, which was always heading towards failure due to the values in the argument not being known non-calculator ratios. A step back and care of thought was needed, but many were not able to find a successful way through.

There were some astute students who spotted a useful substitution $\alpha = \theta$ +11 which had the effect of making the working more concise and easier to follow, allowing a compound angle formula to be used to, usually with success, to produce a suitable equation. Various other approaches were also seen, some successful but not covered directly by the scheme, such as:

$1 - \tan^2 \alpha = 2\tan \alpha \tan(\alpha - 45)$

so $\cos^2 \alpha - \sin^2 \alpha = 2\sin \alpha \cos \alpha \tan \tan(\alpha - 45)$

so $\cos2 \alpha \cos(\alpha - 45) = \sin2 \alpha \sin \alpha$

so $\cos (2 \alpha + \alpha - 45) = 0$ and solving from here.

Question 4

This question involving differentiation and integration by parts saw a reasonable amount of marks awarded for most although it was rare to see students able to apply parts appropriately in (c). The most common scores were 6 or 7 marks (parts (a) and (b) correct, and maybe the first mark in (c)) scored each by around 25% of students. Only about 30% scored more than this, usually scoring at least 12 marks if they did so.

In part (a) the overwhelming majority were able to score both marks and very few errors were seen, though some weak attempts were made by students clearly unprepared for the exam.

Scoring was also good in part (b) with almost all equating the curve equations and then obtaining and solving the correct quadratic in x^2, producing the correct limits required for the final part. Some good explanations on the reasons for rejecting the inadmissible solutions to the equation were seen and that allowed a small number who made suitable progress in (c) to pick up the S mark.

The first mark in part (c) was fairly widely awarded although those who attempted to use two integrals separately were unable to progress. Students may well have been taught to do the two areas separately in these questions like this, but students should realise the AEA paper requires some problem solving and think to write the area as one integrand if separate integrals yield no solution, and look for the link back to part (a).

As is common throughout A-level mathematics, earlier parts of questions are often critical in giving students direction in later parts but only a few students appreciated the significance of part (a) to help identify the appropriate parts split required. The small number who used integration by substitution with $u = \mathrm{e}^{x^3 - 2x}$ or $u = x^3 - 2x$ to get $\int \ln u \,\mathrm{d}u$ or $\int u\mathrm{e}^u \,\mathrm{d}u$, which at this level should be a write down integration, usually had some success.

The main approach that led to successfully solutions, though, saw students connect up parts (a) and (b) with part (c), starting with $\int (8x^3 - 3x^5 - 4x)\mathrm{e}^{x^3 - 2x}\mathrm{d}x$, factorising and then using integration by parts correctly with the result of (a). However, only the most able students were able to produce a correct simplified surd form for the final answer.

One interesting approach used by several students (with variants) was to assume an answer of the form $\mathrm{p}(x)\mathrm{e}^{x^3 - 2x}$, differentiate and match coefficients of powers of *x.*

Question 5

This inequality question in a mechanics context proved very tough for most with a significant number of students making a cursory response or no attempt, which was disappointing as previous papers on the new specification have shown such questions will be set. Nearly 20% were unable to score any marks at all, while only about 20% were able to score in excess of 5 marks. The range 1-5 had a fairly uniform distribution. There nevertheless were some fully correct solutions were seen which invariably accessed the S mark.

Part (a) was accessible to most although many responses were unconvincing in reaching the given answer. Many candidates just stated the horizontal and vertical distance differences, without justification, so had no evidence to award the marks. Several arrived at the $\frac{6V}{5}$ by doubling the $\frac{3V}{5}$, thinking this gave the required result. Those that afforded some time to carefully consider the given information, often with a good diagram, tended to score all three of the marks.

The first mark in part (b) was scored fairly widely (though some had the inequality incorrect), but following expansion of the brackets, many did not realise they could now collect terms to form a quadratic that would allow them to progress. Some abandoned their attempts following confusion with the algebra in the resulting expression and others formed and then attempted to solve a quadratic in *d* before applying the required discriminant equation. Those that had achieved an appropriate quadratic more often than not attempted the discriminant but often an incorrect inequality sign was used. The correct three term inequality in *d* was quite rarely seen but those who had obtained it tended to find the correct critical values and choose the outside regions – although many did not appreciate the need to exclude negative values of *d*. Attempts via calculus were seen but tended to only achieve the first mark. The few solutions that scored eight or more marks did tend to pick up the S mark.

Main errors in part (c), where progress was made, were inequality sign errors, collecting a quadratic in *d* and general errors in the algebraic manipulation. It was more common to see use of discriminant than completing the square.

Question 6

There were plenty of marks awarded to students who persevered with this question, particularly in parts (a), (b) and (d), and the modal mark of 6 was achieved by nearly 15% and around 50% of students scoring more than this (across a wide spread of marks). Only 4% scored no marks at all, making early access better than for question 5. About 4% were able to score full marks on the question in contract. It seemed to be a question students enjoyed with many persevering, and exploring the situation via diagrams, even when they could not work out an approach for the likes of part (c) or parts (e) to (g). The mathematics in this question was perhaps a bit more "fun" than the algebra in question 7.

Most got to grips with part (a), producing a variety of acceptable ways to show how the required value was arrived at - some correct explorations taking a bit of work to figure out what they were doing! Some students did not take the time to read and absorb the question carefully here, with some for example thinking that the sloped parts of L_1 were of a different length than the horizontal parts.

Part (b) saw some reasonable scoring, and it as fairly common to be giving all three marks. Part (iii) was the least successful. The number of line segments in L_n parallel to the horizontal in part (i) was often seen with an index of $n - 1$ or $n + 1$ rather than n but many benefited from the follow through allowed for the mark in part (iii) in such cases.

Suitable progress in part (c) was much less common, with mixed results when progress was made. Following students working was sometimes difficult, and some interesting alternatives by bright students were added to the scheme. Those that did make an attempt often had a correct series for the lengths of the sloped sides but there were often errors in their consideration of the horizontals. Those who formed an appropriate series usually were able to apply the correct sum to infinity formula. A few made progress by investigating the series of total lengths.

Many students were able to access the two marks in part (d) although it was disappointing to see some attempts making errors by resorting to triangles and a rectangle instead of using the area of a trapezium formula. Some efforts used 1 as the height of the trapezium not realising the perpendicular height was required.

Marks in parts (e) and (f) were very rare on the whole, although a fair number were able to pick up at least one of the key elements of how the area of successive trapezia was being affected by the iterative process (usually the increase by factor 3 each iteration). A common error was to believe the scale factor was $\left(\frac{1}{4}\right)^n$ instead of $\left(\frac{1}{16}\right)^n$ while less often the 3^n multiplier was often missing. Only a small amount of correct expressions for part (e) were seen. Those that kept going were sometimes able to progress in part (f) by forming an appropriate sum and finding its value although as with (e) a correct final answer was quite a rare sight.

In part (g) attempts tended to correctly find the area of the triangle although very few could produce a correct sum using the earlier work and the 3x scaling was again often omitted, meaning it was very rare to awarded marks to this part. The S marks were only accessed in a few exceptional cases since most responses did not score enough marks to qualify. Those that did were usually by students of a good enough standard to score at least one S mark, but only the very best were able to score both.

Question 7

The last question was obviously a very challenging one but there were some very impressive attempts here including some which accessed one of the S marks. Even those who could make little impact on part (c) were generally able to pick up some marks, particularly in part (a). Only 2% failed to score any marks with over 85% scoring at least 3. The modal mark of of 8 was scored by 9% of candidates, showing the distribution of scores was wide, though most scores were in the 3-8 band. Less than 1% of candidates produced a fully correct solution, but full marks was achieved by some! Although the mathematics in this question was more dry than that in question 6, the routine algebra in parts (a) and (b) did give access to even weaker students.

The method was well known in part (a) and a lot of successful proofs were seen, indeed errors in this part were rare. The circle equation was rarely incorrect and almost all substituted $y = mx + c$ appropriately. The second mark was withheld on occasion – usually for a sign error or a missing term, with slips being more common with students who needlessly multiplied out all the brackets instead of considering the form of the given answer first. The most elegant solutions were those who immediately spotted they could bracket $\left(c-b\right)$ and not need to fully expand.

Part (b) was algebraically challenging but most did apply the discriminant correctly. Some were unsure of what to do next but many were able to form an appropriate quadratic and solve it. Those who completed the square rather than use the formula were more likely to reach the given result with no errors. There were elegant solutions again keeping $\left(c-b\right)$ intact rather than expanding, but most opted to fully expand and for a quadratic in *c*, leading to greater chance of error. The required degree of organisation required with the algebra was too much for some and many attempts ended early. A small number attempted to use calculus in this part but generally failed to get past the 1st or 2nd M mark.

Part (c) saw some reasonable scoring, although the required justification was not always sufficient. Those who sketched a good diagram and thought about the coordinate geometry were most likely to succeed, appreciating that the normal had to pass through the centre of both circles, and sometimes were able to access an S mark subject to sufficient progress in (d). Many attempts opted for differentiation instead but were usually correct, even though there was no appreciation as to why this happens to give the correct solution, as many tried the same process in part (d) where it does not work.

The final part was often omitted, although the first mark may have been gained by work in (c), and there were many incorrect strategies here including just equating the circle equations, or attempting to equation derivatives. Alternatives to the main scheme were possible but they were extremely rare and most scoring resulted from the route suggested by the given answer to part (b).

Most attempts scored the first mark by correctly finding the centres and radii of the two circles, and the second method was also commonly scored, though progress beyond that tailed off. Identifying the common vertical tangent was incredibly rare, scored in only a handful of cases, usually where the student had drawn a reasonably accurate sketch. Those who were able to form an equation by substituting twice into the part (b) result and equating usually did so correctly, although it was uncommon to see both of the necessary equations arrived at, with many only using one combination of signs. However, most getting this far could get a correct value for m (usually from the quadratic for the second case). A few did continue to find a value for c but were sometimes stymied by incorrect arithmetic, despite the assistance given with the Pythagorean triple. Only a very small number were able to find a correct equation for a common tangent but it was encouraging to see students make it this far – these students usually scored one of the two S marks if they had made at least one good explanation at the appropriate time.

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