

Examiners' Report
Principal Examiner Feedback

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Pearson Edexcel AEA
In Mathematics (9811) Paper 01

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Introduction

Overall, this was a varied paper of an appropriate standard that gave candidates a good opportunity to show what they knew and understood and felt slightly easier to access for all candidates than recent papers. Distinction candidates were given the opportunity to demonstrate flair and provide rigorous arguments, while the less confident candidates were able to attempt questions and score some marks. There were very few blank responses to questions, although some candidates struggled with access to the final question and their attempts faltered early on.

At the merit boundary, candidates performed well on the standard tasks in each question. This was very much the case in questions: 1; 3(ii)(b) & (ii)(c); 4(a); and 6(b) – which, if performed correctly, gave a good foundation over 20 marks. At the distinction boundary, performance was tested in the latter parts of some questions, with questions: 4(b); 5(d); 6(b); and 7(c) onwards - providing good opportunities for candidates to show their skills.

However, there were many whose arithmetic was poor – as evidenced in question 1 and question 6. Other aspects which prevented students from gaining marks included a lack of fluency and efficiency when using standard techniques – for example, on question 1, students using the formula when it was clear that the 3 term quadratic could be factorised and on question 4 (b) when students either simplified the new integral wrongly and were long-winded in, for example, working out the expression in terms of 'u' for $\frac{\mathrm{d}u}{\mathrm{d}x}$.

The other aspect which led to loss of marks was a lack of awareness of the implications of some of the information in a question. This was particularly the case for question 1 where some students failed to get full marks because they did not consider whether their solution(s) satisfied the condition that the coefficient of x^2 should be positive and in question 6 where, despite the information that both blocks were at rest some students used F = ma, with 'a' presumably non-zero.

Summary

Students should:

- Ensure that they can carry out calculations efficiently and accurately without the use of a calculator;
- Learn to carry out standard techniques such as differentiating a quotient fluently and efficiently;
- Write answers involving vectors where the vectors are clearly distinguished from the scalars;
- Be aware that they have used all the information in a question when they complete their solution.

REPORT ON INDIVIDUAL QUESTIONS

Question 1

This should have been a routine question up to the final couple of marks, but many lost marks with evidence suggesting students lacked awareness of common factors and tended to number crunch in the quadratic formula.

The first mark was secure for almost all who took the paper – where students lost marks, it was usually due to incorrectly identifying the coefficients in the expansion.

Most students could proceed from the expansion to get to a correct quadratic by cancelling through by the common factor 'p', albeit in some cases after initial expansion to a cubic. However, in some cases the arithmetic was not accurate in the collection of terms. This is the first point where candidates could have eased their workload by first looking for the cancelling or factorizable terms before attempting to expand.

From the quadratic, most candidates opted to use the quadratic formula, as opposed to factorization, and were faced with some tedious arithmetic as they did not cancel factors earlier. In its simplest case, the process involved the evaluation of $84^2 - 4 \times 32 \times 49$, followed by finding the square root of 784. Since

$84 = 4 \times 21$; $84^2 = 4^2 \times 21^2 = 4^2 \times 3^2 \times 49$ and the other term is 4 × 32 × 49, there is the opportunity to simplify the discriminant by suitable numerical factorization.

This was more of a challenge for those who did no simplification at all and got, for example $512p^2 - 1344p + 784 = 0$. Those who chose to attempt to solve by completing the square faced similar issues, but the candidates who looked for the factors fared much better.

Many were successful in finding the solutions of the quadratic, though some did not take cognizance of the information that "the coefficient of x^2 is positive", so lost marks by not considering it to identify a unique answer to the question. Some of the students who gave some consideration did not always provide a correct reason. Complicated roots from incorrect quadratics were not always easy to disambiguate as it was not always immediately clear if they were greater or less than 1.

There were, however, numerous correct, concise, and elegant responses seen, giving a good early indication on the paper of the aptitude of the candidates.

Question 2

This question was a friendly and well-attempted second question in the paper, testing familiar content in a relatively unfamiliar setting. Most candidates were able to score at least 4 of the 6 marks available here.

In part (a), the vast majority of candidates scored the B mark for a correct formula for D^2, with some candidates using $x^2 + y^2$ in place of D^2 and were not penalised. Occasional sign slips in rearranging meant the mark wasn't scored, but it was more common that the mark was withheld because the candidate failed to recognise that they could make $x^2 + y^2$ the subject of the original implicit equation. Some gave *D* instead of D^2, not paying due heed to the demand in the question.

In part (b), a minority of candidates were unclear on the correct way to minimise D^2 and, instead of differentiating, attempted to complete the square or examine only the minimum of the trigonometric term. For the majority that did differentiate, most found the correct numerator or wrote e.g. $\mathrm{f}(y) = 4 - 3y + 6\sin y$ before differentiating correctly. The most straightforward way of dealing with this was to use D^2 rather than D, so that candidates only had to differentiate $4 - 3y + 6\sin y$ with respect to *y* but some attempted $\frac{\mathrm{d}D}{\mathrm{d}y}$ and made slips, most commonly missing the $\frac{1}{2}$ when attempting the chain rule and as such, the first A mark was unavailable. Those that differentiated generally went on to substitute one of their values into either D^2 or *D*, most commonly $\frac{\pi}{3}$. It was pleasing to see the number of candidates that had analysed the given graph and established an approximate range for *y* and were able to deduce that $\frac{5\pi}{3}$ was not a sensible value to be using. The final two marks did a good job of discriminating between the strongest candidates, as it was rare that candidates chose the correct minimum value, with those that did roughly equally split between analysing where the minimum distance occurred on the graph versus analysing the comparative size of $3\sqrt{3}$ and π. A few attempted the second derivative – this was far easier for D^2 than for *D*.

Question 3

Another accessible question with a little bit of bite at the end, this was answered well with most candidates able to make good progress in parts (ii)(a) to (d).

Part (i) generally yielded all 3 marks or no marks, as either candidates were able to see what to do or could not. The algebra was generally sound with only a small number of cases of algebraic errors, failing to reach $\frac{1}{7}$ after a correct unsimplified expression.

Most who were correct used the main method of taking tangents of both sides and applying the expansion $\tan(A-B)$. Some rearranged first to a sum of arctans but applied the same process to obtain an equation in *k* before solving. A few, also, were successful in the more geometric approach, using right angled triangles, but these responses were only infrequently seen.

The bookwork in (ii)(a) was well done with nearly all students scoring full marks for the proof. Occasional slips lost the final accuracy, but the method was performed well.

Similarly, parts (b), (c) and (d) generally yielded full marks for the standard application of double angle formula, and the straightforward proof. Again, nearly all used the main versions shown on the scheme, with the alternative version only observed on a couple of scripts. The most common error was to lose a square in one of the identities, while a few weaker candidates thought the solutions to (b) and (c) were 2*a* and 4*a*.

Part (e) proved more of a challenge; most could score the first M by writing down an appropriate expression for cos 20° cos40° cos 80° written in terms of '*a*'. Fewer could go much further than that, although some stumbled on one reduction almost by accident before coming to a halt, particularly where earlier error led them to a quadratic in *a*.

Most started by expanding the brackets completely, rather than looking for ways each term could be reduced. However, some did spot that the $a(2a^2-1)=2a^3-a$ was close to the identity from (d) and so used this. Such candidates generally proceeded to the correct answer.

Another common route was to expand the cos 40° cos 80° terms to get $16a^6-24a^4+10a^2-1$ and use the expansion of $(4a^3-3a)^2$ to simplify the former expression to $\frac{1}{4}+a^2-1$ which then led fairly directly to the required value. Other variations did occur but these two were the most common approaches.

Some students fell into the temptation to use $(4a^3-3a)^3$ as its value is $\frac{1}{8}$ but this leads nowhere directly and were ground to a halt before too long. Other, but rarer, approaches included setting *k* = cos20°cos40°cos80° and multiplying both sides by sin20° followed by use of the double angle formula for sine three times and writing cos20°cos40° as ½ (cos60° + cos20°) followed by simplification. The approach by product to sum formula was not actually observed.

Question 4

Questions on integration often prove popular with candidates at this level, with strong performances on previous series, and part (a) of this question proved no exception, with the vast majority of candidates scoring all 5 marks. Part (b) proved much more challenging and gave the strongest candidates an opportunity to shine.

The vast majority of candidates worked through part (a) in a routine fashion, differentiating x with respect to u correctly, substituting everything in, using $1+\tan^2 u = \sec^2 u$ and integrating correctly, before replacing u with $\arctan\frac{x}{\sqrt{3}}$ and including the + c. It was rare for a candidate to struggle in this section, although there were a handful of responses that did not seem confident with integration by substitution and hence failed to differentiate x with respect to u and generally did not score any marks, although the second B mark gave these candidates the opportunity to score one mark.

As in part (a), the majority of candidates worked through the routine work of integration by substitution fairly comfortably, picking up the first four marks quickly, although errors were far more frequent here. The most common mark lost in the early stages of this question was the first A mark, due to errors in simplifying the numerator of $\frac{\mathrm{d}x}{\mathrm{d}u}$, usually due to an error in expanding the brackets leading to $-\frac{6}{(u-3)^2}$ rather than the correct $-\frac{12}{(u-3)^2}$. Occasional slips in rearranging led to incorrect limits and this lost the B mark. A significant minority realised they could reverse the limits by negating the integrand and scored the fourth M mark, although this was not always clear, and candidates should be encouraged to justify steps such as these.

However, the third M mark proved to be the point at which most candidates made no further progress. Despite careful and accurate algebra simplifying the denominator, it was rare for candidates to split the log term in the numerator to reduce the problem to the integrand in part (a) and another instance of the required integral in part (b). As such, it was common for candidates to score between 3 and 5 marks on this part of the question.

Even candidates that scored the third M mark often were unable to complete the problem, as they did not always spot the nested integral. Attempts at integration by parts at this stage (or before splitting logs) were common – perhaps expected as a common route in this type of problem. Those who did spot the change of variables to get the nested integral I usually proceed to complete the process and scored full marks,

although occasional errors or a failure to simplify the definitive answer meant that some missed out on the final A mark.

Candidates that scored sufficiently many marks to be eligible for the S mark generally did score the S mark, as the change of limits was often well demonstrated, even if the reversal of limits was not necessarily clear.

Question 5

The dreaded topic of vectors has proved a stumbling block to many candidates in the past, both at A-level and beyond. This question was, on the whole, answered better than the vectors questions on recent AEA papers, but still saw mixed performance, with many fully correct solutions, as well as the usual poor attempts. Success in parts (b) and (c) largely depended on success in part (a), while part (d) provided a challenge even for the better candidates.

In part (a) many candidates had great difficulty in deciding what to do. Although most realised the answer should be a multiple of **a** + **e**, working out the value of the multiple was more challenging, with many answering the question with **a** + **e** or 3**a** + 3**e** scoring just the B mark. Some did not even have this success and 3**a** was given as an answer by many candidates. It was clear that many students were not able to find the length of a vector under the circumstances given here, but there was a sizeable proportion who did manage to work out the correct vector.

Parts (b) and (c) provided easier access, at least in the method, with most able to formulae correct expression in terms of vectors and use their answer to part (a). But with no follow through, success in obtaining a correct answer therefore depended on whether they had been able to obtain the correct answer to (a).

For part (d) students were expected to equate two different expressions for the vector $\overrightarrow{OX}$. Many did so but also there were some who equated vector $\overrightarrow{OX}$ with a multiple of vector $\overrightarrow{RC}$, while others simply did not know how to get started at all. Successful attempts at this part were somewhat rare.

This is certainly the type of question where a good diagram helps, and many did indeed annotate Figure 2 with the lines, but few drew their own diagram. This did help many to identify the line through *O* and *D* was a multiple of $\overrightarrow{OD}$.

The follow through for the formulation of $\overrightarrow{OX}$ from the extension of $\overrightarrow{OD}$ did give access to one mark for many candidates, but obtaining a suitable expression via the line through *R* and *C* proved beyond most, the lateral thinking required not being on show. Conversely, many who had a notion of what to do extended lines in the wrong direction (via dubious sketches), although this could resolve itself.

Very few who had the correct expressions were able to solve the equations often resorting to substitution which resulted in some complicated manipulations of surds. The handful who spotted that subtracting the equations led to a simple relation between the two unknowns generally went on to score full marks.

A few students resorted to using a Cartesian approach although this entailed a great deal more work; often they did not make it too clear where the origin of their coordinates was, and not many succeeded in reaching the correct answer via such a convoluted route.

Overall, vectors remains one of the harder topics on the specification.

Question 6

The quality of the work produces in this question suggested that candidates have been much better prepared for the applied sections of this paper and, in particular, that the understanding of mechanics has improved significantly.

Part (a) of this question required the candidates to focus on the forces acting on *C* and resolve in the vertical direction. The majority of candidates scored all 3 marks here, but many took a long-winded approach having analysed forces in all the directions at each of *A*, *B* and *C*. Some knew what to do but resolved using sin instead of cos, while others only utilised the tension from one side of the string, using the connection to one of the blocks, which lost all of the marks. It was noticeable that some candidates did not have a clear grasp of the mechanics of the problem or of the mechanics of particles on inclined planes joined with a continuous light string. It was not uncommon to see candidates who were less secure in their approaches to mechanics problems ignore the forces at *C* and instead try to add their equations of motion acting at *A* and at *B*, resulting in an invalid approach to find *T*. Such candidates invariably achieved a limited number of marks in (c).

The force diagrams in part (b) were generally very clear, with forces given a clear direction and labelled appropriately. “Boxes” instead of particles were used all too frequently, but these were not penalised this year. In most cases the forces were acting in appropriate directions, generally scoring the first two marks. The first mark was occasionally lost due to the normal reaction force being missing or pointing directly upwards, or due to the weight pointing opposite to the normal reaction. The second mark (first A) was more frequently lost due to friction drawn acting up the slope or if the weight was split into components, while the final mark was lost most commonly due to the friction being labelled as $F_{\max}$, μR or equivalent. Candidates should be reminded that friction does not always have to be acting at its maximum for a system to be in equilibrium and so $F = \mu R$ should only be brought in later in their work. It was rare to see force diagrams rotated – they were generally drawn in the same orientation as the original diagram.

As mentioned earlier, the general understanding of the mechanics work in this question was very good, but although many candidates worked through part (c) quite efficiently, there was also much erratic work, with candidates trying to resolve and substitute in one go and making work hard to follow. Indeed, the resolution perpendicular the slope often happened as part of the diagram in part (b), or was simply assumed, rather than clearly set out. With S marks for style and communication on this question, candidates should exercise more care to set out clear steps in good order.

However, most were able to proceed, albeit without clear steps, resolving force at *A* (or occasionally just *B*) in both directions parallel and perpendicular to the slopes, applying $F = \mu R$ and establishing limiting value for μ. Many assumed this was the block on the point of slipping and gave the value for block *A* as their answer with no further investigation – despite the number of marks for the question – and so could score only the first 5 marks. Those that worked with both blocks were usually equally successful in obtaining the value for limiting equilibrium of block *B* with similar work, and therefore were able to select a value for μ and more often than not selected the correct value with a reasonable explanation, with some demonstrating an excellent understanding of what was taking place in this scenario.

The significant proportion of candidates that only considered the forces at one block, assuming that it must be block *A* or block *B* that had to be in limiting equilibrium, either just assumed it because of the force diagram asked for, or based their reasoning on the masses of the blocks, or just the components of the masses of the blocks down the slopes, without realising the need to consider both. Just such considerations are insufficient as, for instance, the mass of block *B* being 6*m* changes the situation without changing which mass is larger, and this may be a useful classroom exercise for candidates to experiment with.

A minority of candidates attempted to resolve the forces into vertical and horizontal components, and this made the processing more challenging and invariably led to either an approach that was eventually abandoned or to dropped accuracy marks due to this being a non-calculator paper. Other candidates failed to recognise that the limiting equilibrium meant that $a = 0$ and so used $F = ma$ throughout. These candidates had the second and third M marks available to them, with recovery of the first M1A1 if they later realised that $a = 0$, though this was seldom the case.

S marks were most often awarded due to the solutions being concise, a good explanation of the choice of μ or for good diagrams. The lack of clear working prevented some from scoring both marks, but many who reached the correct conclusion were able to access one. Very few candidates realised that they did not need to restart when looking at block *B* and so solutions were still not as succinct as they could have been.

On the whole, the structure to mechanics problems could still be improved quite dramatically: explaining which directions forces are being resolved in, when $F = \mu R$ is being used, and which blocks are being considered are all areas in which some candidates can tighten their work up.

Question 7

This final question on the paper was well placed, and clearly taxed the candidates, with many unable to make progress beyond part (c)(i), as is befitting for the final question of this paper. It did give the top candidates a chance to really shine with some excellent answers, although part (c)(iii) was conceptually beyond most and did not perform quite as well as hoped. But the first two parts did provide some access to marks for the merit candidates, who generally were able to score well in them.

Part (a) was usually well answered as students realised that the line joining the centres of the circles had length $r_1 + r_2$, so were able to use Pythagoras' theorem on the triangle. Only a handful made no progress, not attempting at all or not formulating a correct strategy by getting lengths of the sides mixed up. For those who could identify the method, very few made errors in the expansion and simplification, so both marks were commonly scored.

Similarly, many were successful with part (b), commonly scoring at least four marks. Candidates who drew a clear diagram generally did better in deriving the given result although in some cases they lost a mark because they did not define or explain the angle θ, instead assumed it. Justification of the angle was part of the demand, but seemed to be missed by some, though many did give it. Forming the area of the trapezium was usually completed first, and usually as a trapezium, though a few split it into a triangle and rectangle. Most realised the result of part (a) could be used, but there were also many cases of reworking the distances from scratch. The areas of the sectors were done well, though whether the second angle was genuinely found or used as it is what gives the result was not always clear. Finally, putting the areas together was done well, and the final accuracy usually followed from correct work, with only occasional slips.

Part (c) was designed to lead students to derive the properties of successive circles so that they could make a good attempt at part (d). However, many started making assumptions of what they were actually being asked to prove and entered circular reasoning and thus lost marks. The diagrams were an aid, rather than a definition of what was happening, and so the pairings of circles should not have been assumed.

Parts (i) and (ii) intended that students should use the results $r_n r_{n+1} = d_{n,n+1}^2$ and $d_{n,n+1}^2 = 2^2\left(\frac{1}{\sqrt{3}}\right)^{n-1}$ where $d_{n.n+1}$ is the horizonal distance between the centres of the nth and $(n + 1)^{\text{th}}$ circles. However, many again here felt the need to rework what was shown in part (a) from scratch each time it was needed, leading to very inefficient work. An awareness of the structure of the question should be taken. Most were able to find the correct value for r_3 after some meandering, but success in part (ii) was less likely. Many guessed that the correct value of k was $\frac{1}{3}$ (usually by working out the first few terms of

d and *r*) but were not able to prove it. However, many correct solutions to the part did follow from the alternative method of using ratios of successive terms in the geometric sequence, which was more efficient than the envisioned main scheme. The latter was used by some to achieve the correct result, but less likely to be successful.

Part (iii) required students to realise that odd and even subscripted *r*'s were both terms in the same geometric series with terms of the form $\left(\frac{1}{3}\right)^{n-1}$. All then students had to do was argue that $r_{2n} = r_{2n-1}$ because it followed once they established that $r_2 = r_1$.

However, students found part (c) (iii) very demanding and often tried to adapt their reasoning in part (ii), which did not work as a solution as it only related alternate terms. This part is where it was most common to assume the result in order to prove it, with many using $\sqrt{r_{2n}r_{2n-1}} = \sqrt{3}\sqrt{r_{2n+1}r_{2n}}$ as a starting point and then applying $r_{2n+1} = \frac{1}{3}r_{2n-1} = \frac{1}{3}r_{2n}$ with no justification of this latter result (which is an assumption of the answer). Overall, this was the first attempted part of the whole question, often being incorrect even when part (d) had significant good work.

On part (d) some creditable attempts were seen by the better candidates taking the paper, by using the given results in the previous section. They were able to separate out regions with odd subscripts from those with even subscripts and were able to recognize and use that the areas in both cases were terms of a geometric series with common ratio $\frac{1}{9}$. This was more often completed by consideration of the first few terms, identifying the pattern and applying the geometric series sum with their first terms and ratio rather than finding the general expressions in terms of *n*, but it could be well reasoned this way. Most who attempted the part were able to identify in some way the correct angle θ for the even cases, and so 2 marks were reasonably accessible (the first M and the B). Scoring beyond that was an indication of a top-grade candidate.

Indeed, many did not even attempt this part, having given up being unable to make progress in part (c), or made some attempt at the first couple of terms before being unable to find a way to make further progress. Since it was designed as a discriminator for distinction candidates it is not surprising that little progress was made by the majority.

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