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In Mathematics (9MA0)

Paper 02: Pure Mathematics

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General

Performance on this paper as a whole was very mixed. There were clearly some very capable candidates who provided clear solutions to the vast majority of problems in the paper. There was a much higher proportion of weaker candidates, with many seemingly unable to access some relatively straightforward questions, and the level of basic algebra (such as solving linear equations) in some cases was particularly poor. Questions involving indices and logarithms particularly caused problems. There appeared to be a time issue with accessing the questions towards the end of the paper for some.

Question 1

Part (a) was generally answered well, with the majority of candidates using h = 0.5 and finding an area rounding to 1.50, but a number completed it with a final answer of 1.505… and consequently lost the final A mark for part (a). The most common error seen was the use of h= $\frac{2}{5}$ which candidates are arriving at because of a misunderstanding in the 'n' seen in the formula in $\frac{b-a}{n}$, they presumably think n is the number of entries in a row of the table ignoring that the first column represents x_0 and y_0. Those candidates who calculated the width of the trapezia independent of the formula $\frac{b-a}{n}$ were usually more successful. The formula was set up correctly on most occasions, with the most common error being the lack of exterior brackets, often resulting in 4.95 as an answer. There were some candidates using a variation of the formula, with the $\frac{1}{2}$ absorbed into the brackets, and a few worked out the areas of four separate trapezia, usually successfully.

Success in part (b) was mixed, with around half the candidates multiplying their answer by 3 and the others multiplying by 9. A minority of candidates restarted, losing access to marks in this question.

In part (c), the mark was only available to those who arrived at an answer rounding to 4.5 in part (b). Answers were often concise and clear, stating that their answer was correct to 2s.f. or 1d.p. and therefore quite accurate. Others went for a percentage error approach, which was also acceptable and usually completed successfully. The main error in this part was that candidates misunderstood what was being asked of them, and instead arguing that the answer was an underestimate, confusing this with another common trapezium rule question.

Question 2

This proved to be a demanding question for many candidates, with false starts and seemingly random statements. Those who were able to make some progress generally gained the initial method mark for expressing one of the line segments in terms of the difference of two position vectors, but many candidates were unable to make further progress. Unfortunately, the addition of two position vectors was a common error. Diagrams helped with some responses, but they frequently depicted OP, OQ and OR as collinear, which tended to cause more confusion. The most common approach amongst those who were able to make further progress were either $\overrightarrow{PQ} = \frac{1}{3}\overrightarrow{PR}$ or $\overrightarrow{OQ} = \overrightarrow{OP} + \frac{1}{3}\overrightarrow{PR}$. Vector notation was often poor, for example Q being used to denote a vector rather than a point, leading to such confused statements as Q = 1/3 PR.

Question 3

This was a fairly accessible question for prepared candidates and provided an early source of marks for many. Generally, most candidates recognised the need to use the power law for logs and correctly obtained $2\log(4-x) = \log\,(4-x)^2$, then proceeded to remove the logs. In fact, many candidates jumped immediately to $(4-x)^2 = (x+8)$ with no sign of logs whatsoever in their solution. This was condoned although it must be noted that combining steps of working in a 'show that' question can be risky. Some candidates diligently wrote out $10^{\log\,(4-x)^2} = 10^{\,\log(x+8)}$ before removing logs, others subtracted $\log\,(4-x)^2$ from both sides and used the log subtraction law to combine the log terms before removing the log. Both approaches were often successful although the latter tended to be the riskier of the two as some candidates forgot that $10^0 = 1$ and instead obtained $\frac{(4-x)}{(x+8)} = 0$ which was then fudged to give the required solution. Those candidates that did not recognise the need to employ the power law for logs early on in their solution made very little progress. Disappointingly, some candidates failed to earn the final mark in part (a) as their final line was missing the "= 0". Candidates should take care to check their final line matches the printed answer in a 'show that' question.

The first part of part (b) was straightforward and gave an opportunity to re-enter the question for those who had come unstuck in part (a). Indeed, for some candidates this was the only mark attained in this question. It was surprising that a number of candidates left their 'solution' as $(x-1)(x-8)$ or gave 'solutions': $(x-1)$ and $(x-8)$. Only a very small number of candidates incorrectly obtained $x = -1$ or $x = -8$.

The second part of part (b) was more discriminating and a careful explanation was required here. Most candidates were able to identify $x = 8$ as the value which was not a solution. However, in order to gain credit, it was also necessary for candidates to make specific reference to the fact that $\log(4-8)$ is undefined. Too many candidates simply stated 'logs can't be negative' which was incorrect and quite different to 'you can't take logs of a negative number'. Candidates should be reminded that reasoning should be precise and specific.

Question 4

This was generally well done, and most candidates scored full marks. A few candidates missed out the brackets around the 2x which usually led to a = 6. Several candidates made a mistake when finding the correct coefficient of x^4 and scored no marks. This was either because the power of a was incorrect or the binomial coefficient was incorrect or occasionally completely missing. The most common error was having the wrong power of a, usually as a^4 or sometimes a or a^7

Several candidates used $a^7(1 + 2x/a)^7$ and errors with the power of a were also common with this method. Some candidates forgot to multiply by a^7 and some forgot to divide the 2x by a.

Question 5

Nearly all candidates combined the equations correctly and gained the first mark. Many then struggled to progress further. A few made mistakes with the indices such as changing $3(2^x)$ into 6^x but the most common mistake was attempting to take logs incorrectly, usually $\log 15 - \log(2(2^x))$ or $\log(15 - 2^{x+1})$ being wrongly expanded to arrive at $\log 15 - (x + 1)\log 2$.

Those who realised $2^{x+1} = 2(2^x)$ usually went on to solve correctly, giving a correct exact answer and therefore gain full marks.

Candidates need to understand that seeing an equation with an unknown index does not automatically mean that it is a question involving logarithms.

Question 6

As would be hoped, most candidates scored some marks on this question. Many found part (a) quite straightforward and there were a good proportion of candidates who gained full marks. Candidates used various approaches to find A, B and C, but the most common tended to be long division. There were a significant number of candidates who performed a completely correct division, but were unable to relate their answer to A, B and C and so lost the accuracy marks. There were many more errors seen when students attempted to multiply (Ax + B) by (x + 2) and compare the numerators, and when candidates selected values of x to substitute in, any errors usually cost both accuracy marks. In comparison, those who used long division were more likely to make an error only in the remainder ($-3 \ - \ +12 \ = \ 9$ being a common slip) and so secure the first accuracy mark.

In part (b), a pleasingly high number of candidates who had found values for A, B and C were able to successfully integrate to gain the first two marks, often aided by the follow through mark that was available. Candidates generally substituted the limits correctly and there was also a relatively good use of the laws of logarithms to combine their terms, albeit with occasional sign errors. The most common being "$-15\ln 8 - (-15\ln 2) = -15\ln 8 - 15\ln 2$". It was not uncommon for a candidate to then incorrectly combine this to get "$-15\ln \frac{8}{2}$". Most success was seen where candidates changed the ln (8) into ln (2^3) and then 3 ln(2) before combining the two $\ln 2$ terms.

Question 7

In part (a), most candidates used a correct method to differentiate, the majority using the quotient rule. A few applied the rule the wrong way round (uv' – vu')/v^2. Candidates who initially wrote the quotient as $2x^{\frac{3}{2}} + \frac{1}{2}x^{\frac{1}{2}}$ were often more successful with the differentiation. A few candidates forgot about the 4lnx term but most dealt with this correctly. Errors from missing brackets or when simplifying their differentiated expression, in particular dealing with the powers, meant that many did not gain full marks in this part.

In part (b), although almost all candidates made dy/dx = 0 and reached $12x^2 + x - 16\sqrt{x} = 0$ the majority then failed to make progress and did not gain any marks. Several made no attempt to rearrange this equation and others made x^2, x or √x the subject but did not make the key step of dividing by √x first.

Part (c) was generally well done, with most candidates getting part (i) correct. Some candidates left out part (ii) and a few made an error with their accuracy here, 1.15651 and 1.1565 being seen a few times.

Question 8

This question was very well answered, with many candidates gaining full marks. Candidates who used the factor theorem (solving f(-4) = 0 to find a = 6, as in the main scheme) were more successful than those who attempted long division, which invariably went wrong and in some cases resulted in a remainder containing '*x*'. Typical mistakes included: solving f(4) = 0 instead of f(-4) = 0 (usually forfeiting 2 marks), mistakes in integrating the '*ax*' term and forgetting the constant of integration or adding it in at the end.

It was noted that some candidates were able to score full marks in this question without explicitly finding *a* i.e. by considering (x + 4) ($2x^2$ ....-3) and deducing the *x* coefficient of the quadratic directly.

Question 9

This question proved to be quite challenging for many candidates and awarding full marks was rare. Nonetheless, most candidates recognised the need to set up simultaneous equations in A and B and were often able to use the information provided in the question to establish at least one equation linking A and B. Usually problems arose initially with the $18 = A - Be^0$ which was frequently incorrectly simplified to $18 = A$ or sometimes $18 = A - 1$. Indeed, some candidates assumed immediately that A = initial temperature = 18 as is sometimes the case in modelling questions. Such errors proved costly as candidates were then limited to one mark from four in part (a). It was pleasing to see that most candidates who managed to set up the two equations correctly were often unphased by the presence of $\mathrm{e}^{-0.7}$ as a coefficient of B. Often this was rewritten as a decimal approximation before solving for B. This was acceptable although some candidates did not provide sufficiently accurate approximations and so lost a mark for values of A and B that were not accurate to 3sf (51.7 and 69.7 were sometimes seen). Candidates also lost a mark here for being too accurate and giving their final values of A and B to 3dp for example. Candidates should be advised to check the question carefully for the required degree of accuracy. Unfortunately, it was quite common for candidates to find correct values for A and B but then fail to state the equation of the model in full which led to the loss of one mark.

Part (b) was quite discriminating. Occasionally, candidates noted that the maximum temperature according to the model is 69.6°C but the most common approach taken by candidates was to set $\theta(t) = 78$ and attempt to solve for t. Some candidates were unable to solve the equation but allowed their work to peter out without comment. However, a good number of candidates correctly noted that a solution was not possible - recognising that the model would not reach the boiling point of ethanol which was sufficient for one mark. It was also common however to see minus signs conveniently disappear in order to obtain a solution for t at all costs. Such candidates usually obtained $t = 25.9$ and concluded that the model would be appropriate up to this time; or obtained $t = -25.9$ noting that 'time cannot be negative'. A significant number of responses gave general comments relating to the model being inappropriate once ethanol's boiling point was reached - such responses were not creditworthy. Unfortunately, errors in the calculation of A and B from part (a) sometimes resulted in a version of $\theta(t) = 78$ which could legitimately be solved which precluded the marks in (b). It was extremely rare to award the second mark in part (b) as candidates almost always failed to acknowledge that the model was inappropriate because the maximum value of 69.6°C is significantly lower than the boiling point of 78°C.

Question 10

Many students were able to get started in part (a) with correct use of cos(2A + A) alongside the addition formula. Candidates who managed this, regularly went on to apply the double angle formulae correctly to achieve an expression in cosA only. Often circuitous routes were taken, most notably with the use of $\cos 2A = \cos^2 A - \sin^2 A$ and then making a second substitution for $\sin^2 A$ (this sometimes resulted in bracketing and/or sign errors). A small number of candidates added a proof for the double angle formulae from the addition formulae even though this was unnecessary. A high proportion of students who managed to get the first mark went on to get at least 3 if not 4 marks in this part of the question. It was very much an all or nothing question with many only getting the first mark. A significant number presented their work in a way that was sometimes difficult to follow even if they did manage to score full marks.

In part (b), it was common for candidates to achieve no marks for part (a) and then full marks for this part. Most of the students gained the first method mark and managed to produce an equation in cosx only. Mistakes were made with signs and brackets. In particular, candidates failed to write brackets around 4cos3x – 3cosx and hence would obtain an incorrect quadratic equation to solve. Several candidates 'solved' the cubic/quadratic equation using the polynomial equation function on their calculator and did not show any evidence of their working. Some incorrect equations led to complex solutions but most of these candidates still did not realise that they had made an error. A large number of candidates divided by cosx to simplify their expression but they failed to recognise this lost a solution and therefore were not awarded the final mark. A small number of candidates failed to gain any marks on this part as they replaced the right hand side with cosx but left the left hand side with cos3x and then proceeded to treat this as a cubic/quadratic. When candidates had identified the correct equation and solutions they were very good at finding all the solutions in the range. A large number who did get solutions did not include -90° or included 180° and therefore lost the final mark.

Question 11

Part (a) of this question was generally well answered, with most candidates being able locate *P* correctly. A few candidates launched into some lengthy algebra, in some cases resulting in values for x and y bearing no relation to the position of *P* on the diagram.

Answers to part (b) from this cohort of candidates were very disappointing and displayed an overreliance on algebra and poor understand of modulus graphs. Very few candidates identified $x = -10.6$ as the solution to the equation. Instead most answers wrote down the solution to $3x+40 = 2(x+4) – 5$ $\{x =-37\}$ as well as $x = -10.6$, scoring M1A0. A few candidates used a calculator to directly write down the correct value of *x* to gain both marks – perhaps not a bad strategy for students who are weak at modulus graphs. A simple check on a calculator would also have established that only $x = -10.6$ was a solution to the printed equation.

Part [c] of this question was one of the most challenging parts of this paper, with hardly any candidates gaining all 3 marks. Candidates seemed unable to 'visualise' the question and see directly that there would be an intersection if *a* was greater than 2, so the B mark was hardly ever gained (and consequently the A mark was immediately lost). The M mark for considering *P* and attempting $a = 5/4$ was occasionally gained, although as above this often entailed long winded algebraic methods e.g. solving simultaneous equations to find *a.*

Question 12

Many candidates left the entire question or parts of this question completely blank and clearly found it difficult to access the content being assessed here, perhaps due to a lack of familiarity with integration using parametric equations. Many tried to establish the Cartesian equation to answer various parts. That said, there were many candidates who provided clear and concise solutions to each part.

In part (a)(i), most candidates recalled the formula for integrating parametric equations and knew to find $\frac{dx}{dt}$. Awareness of the double angle formula for sin2t was good. The main problem caused for these candidates was a lack of "dt" throughout their work, and only included this in the final line, losing the final accuracy mark. There was a significant proportion of candidates who attempt ed some differentiation using the chain rule: $\frac{dy}{dx}$= $\frac{dy}{dt}$ x $\frac{dt}{dx}$, scoring no marks.

In part (a)(ii), many knew that the integral was a multiple of $\cos^3$ t but had trouble getting to the printed answer of 20 with correct steps. As the answer was given, it was a requirement to see the limits calculated separately as 0 – (-20) = 20. Integration by parts was a common approach for unsuccessful candidates, while others attempted to use a substitution, often not using the necessary u = cosx. Those candidates with an understanding of the integration of $f'(x)[f(x)]^n$ were generally very successful here. Some lost the penultimate accuracy mark usually due to a sign error.

In part (b) many candidates who had found part (a) difficult gave up and lost the opportunity of scoring some easier marks. Many candidates who scored no marks elsewhere were still able to access at least the first two marks in part (b) by setting sin2t = $\frac{4.2}{5}$ and solving, frequently getting at least one correct angle; but too many of these found their second value of t by subtracting their first value from π instead of calculating π – $sin^{-1}(0.84)$ before dividing by 2. The following mark was for finding two values of x, but many simply substituted their first value in to find x, thinking that this gave them the width of the walkway. Too many marks were lost by approximating too soon and hence not having values with the required accuracy. A few lost the last mark because they omitted the units.

Question 13

Part (a) was often answered correctly and candidates knew to set the denominator equal to zero and solve to obtain a value for k. Unfortunately, candidates sometimes left their answer as $x = \mathrm{e}^2$ which was, of course, incorrect. Some candidates gave the inexact answer of $k = 7.39$ which was condoned. Commonly seen incorrect answers included $k = 0$, or $k = 1$. A number of candidates gave the value $k = 3$ suggesting that the expression in the denominator had been incorrectly interpreted as $\ln(x-2)$ rather than $\ln(x) - 2$ as was stated. A small number of candidates wrote "there is no k in the question" perhaps failing to spot its presence in the domain.

Part (b) was attempted by most candidates although it was not uncommon to see attempts to find the inverse of $\mathrm{g}(x)$ instead of differentiating. The differentiation in part (b) was however correctly carried out by many candidates, with the majority using the quotient rule. Those who stated the correct formula and the individual components of *u*, *v*, *u*′ and *v*′ were often more successful. A few used $\left(\frac{dv}{dx}\right)^2$ instead of v^2 in the denominator, while others made slips on expanding the bracket $3(ln(x) - 2)$. Some attempted the product rule, usually with less success.

Many candidates did not attempt to simplify the numerator of g′(*x*). Often those that did made slips and it was frustrating to see candidates losing marks due to missing brackets and sign errors when expanding. It was common to see numerators incorrectly simplified to $\frac{-13}{x}$ or $\frac{5}{x}$ although many did manage the correct simplification to $\frac{1}{x}$. Some candidates unnecessarily expanded the denominator, sometimes incorrectly writing $\ln(x^2)$ instead of $(\ln x)^2$. Candidates who managed to correctly simplify their expression for g′(*x*) argued correctly why g′(*x*) > 0 for all x in the domain, but some simply stated this with no reason or gave an incomplete argument of "$x > 0$ so $\mathrm{g}'(x) > 0$" and lost the final mark in this part.

In part (c), most candidates only gained one out of two available marks as they usually considered only the set of values of a for which the numerator is positive by solving $3lnx - 7 = 0$ to obtain $a > e^{\frac{7}{3}}$. Usually no consideration was given to the case where the numerator and denominator are both negative and the few that did solve $lnx = 2$ usually failed to state $0 < a < e^2$.

Question 14

Part (a) presented some thinking challenges for many candidates, in particular spotting that a = b = r in their equation for the circle. About half of the candidates were not able to deduce the correct equation of the circle. The most commonly seen incorrect equations were $x^2 + y^2 = r^2$, $(x + r)^2 + (y + r)^2 = r^2$ and $(x \pm a)^2 + (y \pm b)^2 = r^2$. Some of these candidates managed to gain the method mark for using $y = 12 - 2x$, but a disappointingly high number didn't progress. Relatively few candidates who initially used a and b, correctly replaced them with r to attain at least one mark. Some candidates tried to use a sketch to help them. This did allow some to identify the centre as (r, r), but many put the circle in the wrong quadrant and proceeded to use $(r, -r)$ or $(-r, r)$. The majority of candidates who gained the B1 and M1 expanded their expressions correctly to give the correct equation and attain the A1, although the algebra involved in squaring the 3-term expression $(r^2 - 24r + 144)$was not always carried out correctly. Candidates were generally more successful when they expanded $(y - r)^2$ first before substituting $y = 12 - 2x$.

Part (b) proved to be more accessible to most candidates. Many recognised the need to use the discriminant and equate to zero, though poor algebraic manipulation often cost them the accuracy marks. Almost all candidates used a calculator to solve the quadratic, though there were examples of the quadratic formula being used, mainly correctly. A small number resorted to calculus to find a gradient, but very few successfully attempted to differentiate their equation and set the gradient to -2. A few tried to use the idea of gradient or even equate the equation with $12 - 2x$.

Question 15

A number of the responses were completely blank suggesting perhaps that candidates had run out of time to complete this question. In part (a), very high proportion of the candidates had some idea what the layout of the proof looked like yet only around 50% were able to complete it accurately and rigorously. There were many solutions containing the final the term of S_n as ar^n rather than ar^{n-1}. Candidates who had the correct initial sequence regularly went on to complete the proof correctly. Only a small number prematurely factorised. Some were trying to apply the method of proving the sum of an arithmetic series instead, hence losing the majority of the marks.
In part (b), the first method mark was gained by the majority of students. Some didn't divide by "a" or wrongly cancelled r^{10} and r^5 in their equation, so lost the first accuracy mark. However, many of the students who gained the first two marks continued to gain the last two marks by dealing with the quadratic and achieving the correct solution for "r". A few candidates used (n - 1) in the formula rather than n and a number of candidates got confused with n and r, replacing r = 10 and 5 in the denominator of each fraction. Only around 50% realised that they had ended up with a quadratic equation in r^5 and candidates who did not cancel the "a" out early often ended up with an overcomplicated equation which they could not solve. Very few did not eliminate r = 1 if they found it, although a few solved the quadratic and then forgot to cube root the answer and so had r = 3.

Question 16

This was a very poorly answered question, with the majority of candidates not writing anything at all.

A fairly common attempt was to only split the natural numbers into odd/even cases and square $2n$, $2n+1$, which gained no marks.

Many students who obtained any marks on this question seemed to stumble on these more by chance than by considering the problem. The problem mentioned that the square was to be a multiple of 3 or one more than a multiple of 3 and many students were able to write this as $3n$ and $3n + 1$. Some went on to square these and show that the result was also a multiple of 3 or one more than a multiple of 3. Few students realised that they needed a third case (e.g. $3n - 1$ or $3n + 2$) to cover all integers, and as a result two marks was the most that could be achieved.

It was very rare to see full marks scored in this question. Candidates who did gain full marks typically presented model solutions with thorough explanations and conclusions.

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