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International Advanced Level in Pure Mathematics P1

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General Comments

This paper proved to be a good test of learners' ability on the WMA11 content and plenty of opportunity was provided for them to demonstrate what they had learnt. Marks were available to learners of all abilities.

In general presentation was very good. The learners often showed all the work required using appropriate mathematical notation. However, some learners demonstrated an over-reliance on calculators, for example when solving quadratic equations, when the warnings in the question were to 'show all stages of your working' and 'not to rely on calculator technology'. This was particularly evident when quadratic equations were solved on a calculator and the corresponding factorisation written down incorrectly. This was particularly evident in question 5(b).

Question 1

In part (a) most learners were able to differentiate to obtain at least one correct simplified term. There were a few learners who did not differentiate the middle term and hence did not score all marks available.

In part (b) learners were able to substitute $x = \frac{1}{4}$ into their gradient function from part (a) to achieve a gradient value of 6. Most learners who achieved the first method mark in this part went on to use the correct method to find the equation of the tangent to the curve. There were very few learners who found the equation of the normal.

Overall, the question was very well answered by learners and was a good source of marks early in the paper.

Question 2

This question, assessing accuracy of expanding and integrating a set of triple brackets, was very accessible for the vast majority of learners. For those that did not score full marks, this primarily occurred as responses did not simplify a term.

Most learners attempted a full expansion of the brackets before attempting any integration. On a rare occasion the integration was not attempted afterwards. The majority of learners began the expansion with the squared term and usually showed the separate unsimplified components when combining the result with the third bracket. Occasionally $\left(x^2+9\right)$ was seen as their result from the squared term. There were also a few other errors in this result such as $-3\times-3=-9$. A number of learners omitted placing brackets around their first step but this did not usually result in any further errors. Attempts to integrate were usually successful and most included the required "+ c". The final mark was most commonly lost by those responses where results were not fully simplified, e.g., final coefficients $\frac{2}{4}$ or $\frac{12}{2}$. Occasionally, the "*x*" was dropped from the last term, $45x \rightarrow 45$ in the final line. Sometimes learners seemed unsure about the steps for integration compared with those of differentiation, e.g., $2x^3 \rightarrow \frac{6x^4}{4}$, or they differentiated rather than integrated, but these misunderstandings were uncommon.

Question 3

This question, assessing the cosine rule and area of a triangle formula, proved to be a difficult question, with many learners appearing unsure of how to begin. However, the question did serve to discriminate quite effectively, with a good spread of marks and with many proceeding routinely to the correct answers for both parts.

In part (a), many learners approached this question with the idea that the angles of the triangle were in the corresponding ratios to their sides. This often resulted in the largest angle being 81.8°, which scored M0A0 here. Learners who used the cosine rule correctly were able to almost always arrive at the correct value of $\theta = 108.2°$, although some learners did not gain the accuracy mark by writing $\theta = 108°$.

Occasionally, the cosine rule was sometimes used with the lengths of the sides in incorrect positions, while others opted to find all three of the angles, apparently unclear that the largest angle of a triangle is opposite the longest side.

Very few learners used anything other than 2, 4 and 5 (or 2*x*, 4*x* and 5*x*) for their calculation although the use of $\frac{2}{11}, \frac{4}{11}, \frac{5}{11}$ was seen in some instances.

In part (b), there were many approaches which could score full marks but the majority who were successful used a variable and began correctly with $\frac{1}{2} \times 2x \times 4x \sin 108.2° = 140$. These learners could then proceed to a value for x^2 and then find the shortest length for 2*x* of 12.1(cm). Some very intuitive work was seen from learners who used $\frac{1}{2} \times x \times 2x \sin 108.2° = 140$ and therefore arrived at the required length of 12.1(cm) directly. The most common error was incorrect simplification of the left-hand side of the equation, with one of the variables being lost, achieving an equation such as $4x \sin 108.2° = 140$. These learners were then unable to score the method mark for taking the square root to find x.

Learners who used an incorrect answer from part (a) could gain the B1M1 if they followed the correct method outlined. Learners who used a different combination of sides in their area formula could also score full marks if they matched the correct angle to the sides chosen, e.g., $\frac{1}{2} \times 4x \times 5x \sin 22.3° = 140$ where "22.3" was their smallest angle.

There was, however, a significant proportion of learners who assumed $\frac{1}{2}\times 2\times 4\sin 108.2°=140$ (without a variable) and the majority of such learners did not recover this by using a suitable scale factor method.

Question 4

Very few learners scored all marks available for this question.

Many different approaches were seen in part (a). Most learners gained at least 1 mark for the correct use of at least one index law and many learners reached the correct answer through correct processing, although some did not gain the accuracy mark due to arithmetic errors. Some learners simplified the right-hand side and equated the power to $2p - 5$, while others split the left-hand side and rearranged. Most learners attempted to use a common base of 3 throughout the equation and then equated the indices. For example, $3^{2p-5}=3^{-2}\times 3^{\frac{3}{2}}$ leading to $2p-5=-2+\frac{3}{2}$ and then solving this linear equation to find the value of p. There were some attempts to use a common base of 9, but this approach was more difficult, and it generally was not awarded marks. Some learners appeared to be drawn towards a base of 9 by making an initial mistake such as $3\times 3^{p}=9^{p}$, and this often resulted in no marks.

Some learners used logs, which was an acceptable approach provided a correct application of at least one law of indices had been seen first.

Some learners attempted to remove the indices by taking logs base 3, for example:

$\log_3 3^{2p-5}=\log_3 3^{-2}\times 3^{\frac{3}{2}}=\log_3 3^{-\frac{1}{2}}$ leading to $2p-5=-\frac{1}{2}$, and then solved this linear equation to find the value of p. Some learners rearranged the original equation, for example by multiplying by 9 to remove the fraction on the right-hand side.

Common errors seen were:

- Incorrect manipulation of the left-hand side, for example $3^{2p-5} = 9^{p-5}$
- On the right-hand side, to multiply rather than add the indices e.g. $3^{-2} \times 3^{\frac{3}{2}} = 3^{-3}$
- Changing the base number when applying index laws e.g. $\frac{3^{\frac{3}{2}}}{3^2} = 1^{-\frac{1}{2}}$
- Algebra or arithmetic errors, for example when multiplying both sides of an equation by a constant, not multiplying one of the terms in the equation, or reaching $2p = \frac{9}{2}$ and then removing 2 on both sides to get $p = 9$

In part (b) most learners were successful in scoring the first two marks for reaching a correct quartic equation (or a quadratic equation in a different variable).

A good number of learners then showed a suitable method to solve their equation for x^2 before taking square roots to find x. Quite a few learners used a substitution for x^2.

Common errors seen included:

- Not showing a correct non-calculator method in solving the quadratic equation.
- Attempting to solve using incorrect factorisation.
- Only giving the positive root when solving $x^2 = 8$
- Using the substitution $x = x^2$ and then thinking that $x = 8$ and $x = -5$ were the final answers.

Other errors seen included:

- A small number of learners incorrectly simplified the fraction on the right-hand side. This approach scored no marks. For example, $\frac{36}{x^2-4}$ becoming $\frac{36}{x^2}-9$
- Other errors in cross-multiplication, e.g. rewriting the initial equation as $36\left(x^2+1\right)=\left(x^2-4\right)$
- A number of scripts were seen where the learner multiplied the right-hand side of the original equation by $\frac{x^2+4}{x^2+4}$, possibly arising from the challenge with rationalising the denominator of an expression involving surds.
- Many learners seemed to employ a two-stage method of using the quadratic formula: firstly, evaluating the discriminant and then setting up a second expression to determine the roots. However, a number of learners stopped after determining the discriminant, believing they had a solution.
- For responses that did give a correct method for solving the 3TQ, leading to values for x^2 (or implied by correct values of *x*), some did not gain the final mark for either not including the negative solution, or including incorrect roots such as $\pm\sqrt{5}$, $\pm\sqrt{-5}$ or $\pm\frac{1}{\sqrt{5}}$
- Examples were seen where the learner achieved $x^2=8$ but then solved to $x=4$
- After reaching the correct quartic equation, some learners attempted to take a square root of each term, reaching, for example $x^2-3x-40^{\frac{1}{2}}=0$

Question 5

In part (a), most learners were able to correctly complete the square to the given form. However, there was a significant number of learners who did not demonstrate the correct value for c due to arithmetic mistakes.

In part (b), most learners correctly deduced the equation of the line by using the answer to part (a) or by using calculus to find the coordinates of the minimum point. Most then successfully interpreted the question and equated the curve and their line to achieve the correct quadratic equation. A good number of learners then went on to use calculators to find solutions despite the calculator warning at the start of the question. Learners are advised that the instruction not to use a calculator in cases like this, when the solution to a quadratic equation is required must be followed.

In part (c), most learners did not obtain full marks since they did not identify all of the inequalities needed for the region R. Most were able to achieve the first B mark using their equation of the given curve and that of the line l found in part (b) but did not restrict the x values for the second mark.

Question 6

This question, assessing sketching of reciprocal graphs and transformations in part (a), and intersection of curves, use of the discriminant and inequalities in part (b), appeared challenging for some learners.

Although there were many fully correct sketch graphs seen in part (a), learners should take care when sketching to ensure that asymptotes are clear and that the shape is appropriate.

Learners should fully label any sketch with intersections and asymptotes. In particular, it was common to see $2k$ labelled on the x-axis where the asymptote intersects, but with no equation of the asymptote present.

The main error seen was the incorrect labelling of the intersection on the y-axis as $(0, -2k)$ but the asymptote was occasionally seen labelled as $x = 2$ or $y = 2k$.

Many sketches also included an incorrect horizontal asymptote, but these often scored the first M1 as they did have a correct shape in the 1st quadrant. Some learners did not show they were able to correctly apply the translation involved, shifting the graph vertically or horizontally to the left, and did not score any marks as a result.

In part (b), most learners made a good attempt at the cross multiplication after equating the curves, although some responses used cancelling within the algebraic fraction at the start of the process, and therefore did not score any marks. Occasionally, the "$4k$" was lost during the process or there was a sign error in one or more of the terms and this resulted in an incorrect equation. The A1 was available prior to simplification, rewarding learners for this correct expansion of brackets, but it was quite common

to see $(6-4k)x$ from two previously correct components and this led to an incorrect final answer.

During the process of forming the discriminant it was not unusual to see $16k$ become just "16", thus losing the ddM1 which required b and c to be in terms of k.

Most learners solved the quadratic equation obtained from their determinant correctly (in this case calculator use was allowed) but many only identified the roots or incorrectly chose the inside region. Most responses did not gain full marks as learners did not use the stipulation "where k is a positive constant".

Question 7

This question was very accessible to most of the learners with the majority achieving full marks.

In part (a), most learners were able to use the formula for the area of a sector to determine the radius of 6.03. Once this was achieved, they were able to add to 2.8 to arrive at the given answer. Most learners achieved full marks in this part.

In part (b), learners were able to find the area of the sector using their answer in part (a) and the angle made by the sector to achieve the awrt 181 and then added 30 (area of *OPQ*) to obtain the correct area. Some responses did not add 30 and thus did not gain a mark.

In part (c), most learners were able to find the perimeter of the swimming pool correctly. Most recalled the correct formula for arc length and added the two required arcs and the straight edges. Many learners did not add the straight edges, however.

Question 8

This question was challenging for some learners.

In part (a), stronger responses understood that the equation of the tangent provided them with the value of $\mathrm{f}'(x)$ at $x=\sqrt{2}$ and set $\mathrm{f}'(x)=5$ then solved this to find the value of k, potentially gaining both marks. The most common error seen was setting $\mathrm{f}'(x)=5x-3\sqrt{2}$, sometimes with substitution of $x=\sqrt{2}$. Other incorrect responses included setting $\mathrm{f}'(x)=y$ or 0, leading to a range of incorrect answers. Of the learners who correctly set $\mathrm{f}'(x)=5$, some made arithmetic errors when solving or gave the answer as a decimal, rather than the required exact value.

In part (b), stronger responses took the negative reciprocal of the gradient of the tangent, i.e. $-\frac{1}{5}$ and, using $x=\sqrt{2}$ in the equation of the tangent, found the corresponding *y* value to form the equation of the normal: $y-2\sqrt{2}=-\frac{1}{5}\left(x-\sqrt{2}\right)$

Common errors seen included:

- Using a gradient of 5
- Using their value of k as the gradient
- Using a *y* value of $5x-3\sqrt{2}$ (not substituting $x=\sqrt{2}$ to evaluate *y*)
- Trying to find the intersection point of the curve and tangent
- Attempting to find the negative reciprocal of $x=\sqrt{2}$ or $y=2\sqrt{2}$, or their k value.
- Some learners who used the correct gradient assumed that the constant term was $-3\sqrt{2}$, as in the equation of the tangent.

Arithmetic and algebraic errors were often seen in the rearranging of the equation. However, those learners who used a correct gradient and point on the line could still gain both marks for e.g. $y-2\sqrt{2}=-\frac{1}{5}\left(x-\sqrt{2}\right)$ if this form was reached before the rearranging, since a correct equation in any form was acceptable.

In part (c), many learners correctly realised that finding the equation of the curve required an attempt to integrate $\mathrm{f}'(x)$, followed by calculation of the constant of integration. Marks could be awarded for this even if the work appeared in parts (a) or (b). The first method mark required an attempt at integration resulting in two correct powers. Most learners achieved this, although a minority integrated the term in x^{-2} incorrectly to reach a term in x^{-3}.

The first A mark required correct integration, following through on the learner's value of k. Omitting brackets around their value for k when integrating was a very common response: i.e. integration of $1-2\sqrt{2}$ to $1-2\sqrt{2}x$ rather than the correct $\left(1-2\sqrt{2}\right)x$. This was only condoned if the brackets were recovered during the subsequent calculation of their constant. Learners who had an incorrect but single-term value of *k*, or a decimal, were more likely to reach a correct follow-through expression after integration, and to be awarded the first A mark.

The second method mark required using $x=\sqrt{2}$ and the learner's attempt at y to find a value for their constant of integration. Most learners scored this mark. However, some learners set their integrated expression equal to 0, or another value that was not an attempt at *y*. These responses were unable to gain this mark. Not finding, or including, a constant of integration affected some responses. In these cases, only the first two marks were available. For the final A mark, learners who correctly bracketed their correct exact value of k often scored full marks and those who did not often scored only the two method marks.

In some cases, responses did not gain this mark as they did not write out a full expression for $\mathrm{f}(x)$, stopping after calculating a value for the constant of integration. In other cases, the final A mark was lost due to missing brackets around the value of *k*, as for the earlier A mark. Other copying errors were also seen in the final answer line, preventing attainment of this mark. Since the first 3 of the 4 marks could be gained following though an incorrect value for k from part (a), many learners scored fairly well in this question part, even after unsuccessful attempts at parts (a) and (b).

Question 9

This question assessed trigonometric graphs and transformations and was often very well attempted with many learners scoring full marks. The use of degrees

was not allowed to score any marks in this question, although most learners used the more direct method outlined in the mark scheme.

In part (a), virtually all learners recognised the graph as a transformation of $\sin x$ or $\cos x$. The majority of learners gave the correct standard result $-4\sin x$ with a few showing correct alternatives such as $4\cos\left(x+\frac{\pi}{2}\right)$. A common response, receiving the method mark only, was $4\sin x$. Some learners treated the curve as a quadratic or gave the description of some transformation demonstrating limited familiarity with this kind of question.

The majority of learners scored full marks for all of part (b), although the coordinates were sometimes written the wrong way round, scoring B0B0 in both (i) and (ii). Since these were B marks, the written responses had to be as in the mark scheme, with only equivalent fractions allowed, but not unprocessed such as $\frac{1}{2}\times -4$ instead of -2.

Slips in (i), such as $\left(\frac{5\pi}{4},4\right)$, were not uncommon, while the *x* coordinate was sometimes found by subtracting $\frac{\pi}{6}$ rather than adding $\frac{\pi}{6}$.

In part (ii), some applied the transformation to *x* rather than *y* resulting in an answer of $\left(-\frac{3}{4}\pi,4\right)$ or even $\left(\frac{3}{4}\pi,-2\right)$. A frequent incorrect *y* coordinate was "-8" with "2" or "$-\frac{1}{2}$" occurring sometimes.

This question was, however, generally very well answered, and learners demonstrated their understanding of the transformations of trigonometric functions to a very good standard.

Question 10

This question appeared to be particularly challenging for many candidates. In part (a), stronger responses differentiated the equation of the curve and used the fact that the *x* coordinate of *P* was 0, to find the gradient of the tangent at *P*. A few learners differentiated incorrectly, but this was condoned for the first method mark, providing there was a valid attempt at differentiation and substitution of $x = 0$. These learners were able to gain full marks in part (a), despite this early error, if they obtained a gradient of –2.

When using the negative reciprocal of the gradient of the tangent, many stated that the equation of the normal was $y = \frac{1}{2}x + 5$ with no explicit working for the y intercept, although some showed the substitution of $x = 0$ into the equation of the curve to find the y coordinate at P. Some learners seemed to assume the normal passed through the point (0, 0) and ended up with an equation of the form $y = mx$. Many learners reached the correct equation of the normal and set this equal to the given equation of the curve, leading to a cubic equation, gaining the dM1 mark. The second A1 was also quite widely gained, for reaching a correct cubic with the terms collected on one side, although there were a few arithmetic errors leading to incorrect coefficients in the cubic. Cancelling or taking out a factor of x, leaving a quadratic equation, was essential working for the ddM1, before solving the quadratic equation to find the value of *x* at Q. Solution of the resulting quadratic equation was usually done well, and calculator solutions were acceptable in this question, although some learners lost the final A mark because of earlier rearranging slips leading to an incorrect cubic equation. Some learners went on to find the *y* coordinate, which was not required.

Common errors seen were:

- Not differentiating. An attempt at differentiation was usually required to gain the first method mark. Very few responses deduced the gradient of the curve at point P without differentiation.

- A small number of learners attempted integration instead of differentiation.
- Setting $\mathrm{f}(x)=0$. This would almost certainly result in no marks, unless there was a restart.
- Assuming the equation of the normal to be $y=x+5$ (obtaining the correct *y* intercept, but not finding the gradient). These attempts were unlikely to gain any marks.
- Setting $\frac{\mathrm{d}y}{\mathrm{d}x}=0$ and solving. In some cases, this led to a value of $\frac{1}{2}$ which the learner took to be the gradient of the normal. Thus, it was possible to complete the rest of part (a) and find the correct *x* coordinate of point Q but these responses gained no marks because of the early incorrect working.
- A few learners used the equation of the tangent. These responses could gain the first method mark for a correct curve gradient of -2, but could gain no further marks.
- After equating the equations of the curve and the normal, incorrect rearrangement leading to an incorrect cubic equation.
- A small number of responses did not show any working in dealing with the common factor of *x* in the cubic equation and used a calculator to find the solutions. These responses could not gain the last two marks.
- Factorisation was frequently seen in which the factors did not correspond to the equation, for example $2x^2+\frac{1}{2}x-\frac{5}{2}=0\Rightarrow(4x+5)(x-1)=0$ suggesting use of a calculator although this was not penalised in this question.

Many learners appeared unsure of how to begin part (b). However, learners who set the gradient function equal to $\frac{1}{2}$ often went on to score full marks, finding a correct three term quadratic equation and writing down the correct exact value

for x. In nearly all of these cases, the positive solution was correctly selected. Responses with an incorrect gradient function could score the method marks only, if it was set equal to $\frac{1}{2}$.

Most learners wrote out the quadratic formula with appropriate coefficients in place as their means of solving, although some calculator solutions were seen, but not penalised in this question.

Common errors seen were:

- Setting their $\frac{\mathrm{d}y}{\mathrm{d}x}$ equal to the gradient of the tangent at *P*, i.e. –2 or to 0.
- Setting their $\frac{\mathrm{d}y}{\mathrm{d}x} = -\frac{1}{2}$
- Although appearing to understand that the gradient would be $\frac{1}{2}$, did not have a derivative to equate it with.
- Having reached $x = \frac{-1 \pm \sqrt{61}}{12}$ some learners then gave the *x* coordinate of *T* as $-\frac{1+\sqrt{61}}{12}$