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Examiners' report

MATHEMATICS A

H240

For first teaching in 2017

H240/01 Summer 2022 series

Version 1

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Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers are also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 1 series overview

H240/01 is one of the three examination units for the A Level examination for GCE Mathematics A. It is a two hour paper consisting of 100 marks which tests Pure Mathematics topics. Pure Mathematics topics are also tested on the first half of Papers 2 and 3, and any Pure Mathematics topic could be tested on any of the three papers.

To be successful on this paper, candidates need to be familiar with the entire specification and also have an understanding as to how to apply it to any question. They should be able to draw together their knowledge of different topic areas, so as to devise effective strategies when solving unstructured problems. They should appreciate how different parts of the question may link together, with earlier parts of the question possibly being of use in later parts.

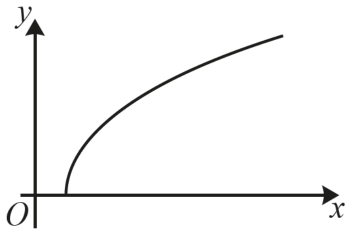
They should be able to make effective use of their calculator where appropriate, but also make sure that adequate detail is given in questions where 'detailed reasoning' is required. When asked to show a given answer, candidates should make sure that their solutions have sufficient detail and not try to include several steps in a single line of working.

They should be able to clearly convey their intentions, through use of correct notation, such as using brackets effectively, and also through use of correct mathematical language. Their decisions should be fully justified with supporting evidence, and reasoning given when discarding any solutions.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• were able to pull together different areas of the specification to answer unstructured, multi-step, questions • gave clear detail of their method, with conclusions fully justified • made effective use of diagrams.	• did not provide sufficient detail or clarity in explanations • did not use mathematically correct language, such as when describing transformations • gave insufficient detail in 'show that' questions, often combining several steps in a single line of working.

Question 1 (a)

1



The diagram shows part of the curve $y = \sqrt{x^2 - 1}$.

(a) Use the trapezium rule with 4 intervals to find an estimate for $\int_1^3 \sqrt{x^2 - 1}\,dx$.

Give your answer correct to **3** significant figures. **[4]**

Most candidates were able to make a good attempt at this question, with many fully correct solutions seen. These tended to make good use of brackets, and work with exact values as opposed to the decimal approximations. The most common error was to interpret 'intervals' as the number of ordinates instead, hence using only three trapezia rather than 4.

Question 1 (b)

(b) State whether the value from part **(a)** is an under-estimate or an over-estimate, giving a reason for your answer. **[1]**

Most candidates could identify that it was an underestimate, giving a convincing explanation as to why this was the case. The most common solutions were to state that the curve was concave, or to explain why the trapezia did not cover the entire area; the latter approach was often supported with a sketch graph. Some candidates seemed unsure as to which specification area was being tested, and referred to upper and lower bounds from using rectangles.

Question 1 (c)

(c) Explain how the trapezium rule could be used to obtain a more accurate estimate. **[1]**

The vast majority of candidates gained this mark, identifying that more trapezia, of a lesser width, over the same interval would give a more accurate estimate.

Question 2 (a)

2 **(a)** Given that a and b are real numbers, find a counterexample to disprove the statement that, if $a > b$, then $a^2 > b^2$. **[1]**

Most candidates could identify a correct counterexample, appreciating that this would occur when at least one of the numbers was negative. Examiners expected to see some evidence of the contradiction, but this was not always the case, with some candidates finishing with, for example, 1 > 4 but not then making any further comment.

Question 2 (b) (i)

(b) A student writes the statement that $\sin x° = 0.5 \Longleftrightarrow x° = 30°$.

(i) Explain why this statement is incorrect. **[1]**

The best solutions either identified an additional possible value for *x*, such as 150^0, or explained that sin was a many to one function. Some candidates lacked precision in their answer; comments such as 'other values are possible' were not fully convincing. Incorrect statements, such as $\sin^{-1}0.5 = 30°$ and $150°$ were penalised.

Question 2 (b) (ii)

(ii) Write a corrected version of this statement. **[1]**

Most candidates were able to identify the required connective and provide a corrected version of the statement. Some candidates instead attempted to include additional values on the right-hand side, but this had to be a fully correct general solution in order to gain credit, and others limited the domain in their solution.

Question 2 (c)

(c) Prove that the sum of four consecutive multiples of 4 is always a multiple of 8. **[3]**

Most candidates were able to gain a mark for writing expressions for four consecutive multiples of 4, with the most common error being $4n$, $4n + 1$, etc. While a few then attempted the product, the majority did attempt to sum the terms and take out a common factor of 8, but this was not always done correctly. Some candidates then spoiled an otherwise correct solution by omitting to provide a conclusion as to why this showed that the sum would always be a multiple of 8.

Question 3 (a)

3 (a) In this question you must show detailed reasoning.

Find the coordinates of the points of intersection of the curves with equations $y = x^2 - 2x + 1$ and $y = -x^2 + 6x - 5$. **[4]**

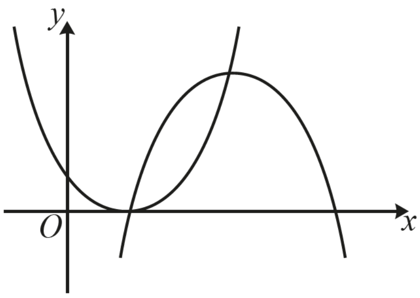
The vast majority of candidates gained full credit on the question by correctly finding the two points of intersection, showing sufficient reasoning. Candidates who did not show detail of solving the quadratic equation could still gain a maximum of 3 marks. Some candidates made assumptions about the points of intersection, based on the sketch provided in part (b), usually assuming that the points were also the stationary points on the two curves. This method had to be fully justified for any credit to be awarded.

OCR support

Some candidates did not seem familiar with the command words, such as 'detailed reasoning' in this question and 'hence' and 'determine' elsewhere on the paper. These are clearly detailed in the specification, and OCR have also produced a command word poster for display in the classroom.

Question 3 (b)

(b) The diagram shows the curves $y = x^2 - 2x + 1$ and $y = -x^2 + 6x - 5$.
This diagram is repeated in the Printed Answer Booklet.



On the diagram in the Printed Answer Booklet, draw the line $y = 2x - 2$. **[2]**

Nearly all of the candidates gained 1 mark for sketching a straight line with positive gradient and negative intercept. Many also appreciated the significance of the points of intersection already found, but a surprising number did not see the relevance of the work already done.

Question 3 (c)

(c) Show on your diagram in the Printed Answer Booklet the region of the x-y plane within which all three of the following inequalities are satisfied.

$y \geqslant x^2 - 2x + 1 \qquad y \leqslant -x^2 + 6x - 5 \qquad y \leqslant 2x - 2$

You should indicate the region for which all the inequalities hold by labelling the region R. **[1]**

Most candidates could correctly identify the required region, which could follow from any straight line that split the common area into two parts.

Question 4 (a)

4 (a) Write $2x^2 + 6x + 7$ in the form $p(x+q)^2 + r$, where p, q and r are constants. **[3]**

Nearly all of the candidates gained full credit on this question. The most common error was forgetting to multiply their – 1.5^2 by their 2 when attempting the constant term.

Question 4 (b)

(b) State the coordinates of the minimum point on the graph of $y = 2x^2 + 6x + 7$. **[2]**

Once again, this part of the question was nearly always correct. Some candidates used their completed square form from the first part, whereas others made a fresh attempt, often involving the use of calculus. Some candidates simply wrote down the correct answer, despite part (a) being incorrect, possibly from use of calculator functions.

Question 4 (c)

(c) Hence deduce

- the minimum value of $2\tan^2\theta + 6\tan\theta + 7$,
- the smallest positive value of θ, in degrees, for which the minimum value occurs. **[3]**

This final part of the question proved to be challenging, with a number of candidates not appreciating the link with work already done and struggling to make progress. A number did try to relate tanθ to their minimum point, with a common error being to attempt $\tan^{-1}$ of both the x and the y value. Despite the structure of the question making the two requests clear, quite a few candidates only attempted the angle and not the minimum value of the given function.

Question 5 (a) (i)

5 **(a)** The graph of $y = 2^x$ can be transformed to the graph of $y = 2^{x+4}$ **either** by a translation **or** by a stretch.

(i) Give full details of the translation. **[2]**

Most candidates could identify that a horizontal translation of 4 units was required, and also that it would be in the negative *x*-direction. To gain full credit, mathematically correct language was required but ambiguous statements such as 'in' the *x*-axis or informal ones such as 'along' the axis were all too common. The most successful approach was to state the correct column vector, thus avoiding the need for any additional description.

Question 5 (a) (ii)

(ii) Give full details of the stretch. **[2]**

This part proved to be more challenging, with around half of the candidates being able to identify both the correct direction and the correct scale factor. Once again, incorrect language was all too common.

Question 5 (b)

(b) **In this question you must show detailed reasoning.**

Solve the equation $\log_2(8x) = 1 - \log_2(1-x)$. **[4]**

This question was very well answered, with many candidates gaining full credit. The most common approach was to first combine log terms and then remove the logs, and this was usually successful. Some candidates first introduced indices, base 2, on both sides but the subsequent simplification of the right-hand side proved to be problematic for some. Despite this being a 'detailed reasoning' question, some candidates went straight from the quadratic equation to stating the root. On this occasion this was condoned, but candidates would be well advised to make sure that sufficient detail is always provided in these types of questions.

Question 6 (a)

6 **(a)** Find the first four terms in the expansion of $(3+2x)^5$ in ascending powers of x. **[4]**

This proved to be another question that was very well answered, with fully correct solutions being very common. The more successful approach was to simply to use the binomial expansion of $(a + b)^n$, as provided in the list of formulae at the start of the paper. A surprising number of candidates instead decided to first reduce it to the form $(1 + x)^n$, which could then cause problems with the factor being taken out often seen as just 3 and not 3^5. Candidates should consider what strategy is most appropriate for the question posed.

Question 6 (b)

(b) Hence determine the coefficient of y^3 in the expansion of $(3+2y+4y^2)^5$. **[4]**

This second part of the question proved to be much more challenging. Some candidates, guided by the word 'hence', did attempt to link the two parts of the question with the most common error being to use $x = 2y + 4y^2$; this could still gain 2 of the 4 marks available. Other sensible attempts included splitting the three terms into two groups and attempting to use another binomial expansion, or attempting a combinatorics method having identified how y^3 terms could be created. Attempts involving the manual expansion of all 5 brackets were rarely complete or successful.

Question 7

7 A curve has equation $2x^3 + 6xy - 3y^2 = 2$.

Show that there are no points on this curve where the tangent is parallel to $y = x$. **[8]**

Most candidates could make progress on this question by recognising that it was an implicit equation and making a good attempt to differentiate it. The derivative was usually correct, but the modal mark on this question was 3 marks as many candidates were unsure as to how to then proceed. While a number did set the derivative equal to 1, a common error was to substitute $y = x$ into their derivative. The correct quadratic of $x^2 + x = 0$ was often seen, but there was often some uncertainty as to how to solve this and only the more able candidates were able to obtain both correct roots. Some candidates found just one of the roots by inspection and others, having obtained $x^2 = -x$, observed that a square cannot be negative hence this equation has no roots at all. To gain full credit, examiners expected to see sufficient detail as to why neither root would yield solutions when substituted back into the original equation. While the substitution was seen, the explanations were often lacking in detail. Just stating that $3y^2 = -2$ was impossible was not enough and, when considering $x = -1$, it was not sufficient to just say that the ensuing quadratic had no roots; this needed to be demonstrated, most typically through considering the discriminant.

Assessment for learning

There will be some questions where the root(s) of an equation are not valid solutions to the original problem. These often occur in 'disguised' quadratics, trigonometric equations and questions such as this one, where candidates had to show that there were no valid points. It is insufficient to simply state 'no solutions' or 'not possible'; candidates should be prepared to give compelling reasons whenever a solution is discarded.

Exemplar 1

7	$2x^3 + 6xy - 3y^2 = 2$
	differentiate with respect to x
	$6x^2 + 6y + 6x\frac{dy}{dx} - 6y\frac{dy}{dx} = 0$
	$\frac{dy}{dx}(6x - 6y) = -6x^2 - 6y$
	$\frac{dy}{dx} = \frac{-(6x^2+6y)}{6x-6y} = \frac{-6(x^2+y)}{-6(-x+y)} = \frac{x^2+y}{y-x}$
	$y = x$ has gradient 1
	$\frac{dy}{dx} = \frac{x^2+y}{y-x} = 1$
	$x^2 + y = y - x$
	$x^2 = -x$
	$x^2 + x = 0$
	$x(x+1) = 0$
	$x = 0$ $x = -1$
	Sub in $x = 0 \Rightarrow 2(0)^3 + 6(0) - 3y^2 = 2$
	$y^2 = -\frac{2}{3}$ invalid as cannot square root a negative number.
	sub in $x = -1 \Rightarrow 2(-1)^3 + 6(-1)y - 3y^2 = 2$
	$-2 - 6y - 3y^2 = 2$
	$3y^2 + 6y + 4 = 0$
	$D = b^2 - 4ac = 6^2 - 4(3)(4) = -12 < 0$
	For $D < 0$, the curve has no real roots.

A good solution to Question 7, with clear reasons given as to why neither root will give a valid solution.

Question 8 (a)

8 **(a)** Substance *A* is decaying exponentially such that its mass is *m* grams at time *t* minutes. Find the missing values of *m* and *t* in the following table.

t	0	10		50
m	1250	750	450	

[2]

Only the most astute candidates seemed familiar with the definition of exponential growth and decay as using the same scale factor for a fixed time period, and were hence able to simply state the two missing values. The most common approach was to set up a model of the form $M = Ae^{kt}$. Candidates were then able to use their model to attempt the two required values, but there was quite often a loss of accuracy in their final answers due to premature approximation of the parameters found.

Question 8 (b) (i)

(b) Substance *B* is also decaying exponentially, according to the model $m = 160e^{-0.055t}$, where *m* grams is its mass after *t* minutes.

(i) Determine the value of *t* for which the mass of substance *B* is half of its original mass. **[3]**

This question was very well answered, with the majority of candidates gaining full marks for setting their model equal to 80 and solving for *t*. A surprisingly common error was to start with the correct equation, but then miscopy it from one line to the next with the index invariably becoming – 0.55*t*. In all questions, candidates would be well advised to check their working for copying errors.

Question 8 (b) (ii)

(ii) Determine the rate of decay of substance *B* when $t = 15$. **[3]**

Most candidates appreciated that 'rate' indicated the need to differentiate, and were able to do so correctly and then substitute $t = 15$. The final mark proved to be more elusive, as both a positive value and units were required in the final answer.

Question 8 (c)

(c) State whether substance A or substance B is decaying at a faster rate, giving a reason for your answer. **[1]**

The more common approach was to attempt to compare the coefficients of t, but inequalities were not always correct due to them both being negative. Some explanations lack precision, simply referring to 'the decay constant' or even just 'k', without specifying what this was. Other candidates picked a value for t and compared either the percentage of the mass that had been lost or the percentage still remaining, or compared the half-life of each substance. The other approach was to compare the actual rates of decay at a given time, usually 15, which resulted in a different conclusion. Either approach could gain credit, as long as the conclusion was supported with empirical evidence and not just vague statements, as was too often the case.

Exemplar 2

8(c)	Sub. A takes 13.6 minutes to decay half its mass Sub B takes 12.6 minutes to decay half its mass ∴ substance B is decaying at a faster rate as it loses its mass more quickly.

This is a good solution to Question 8 (c), in that it provides clear evidence to support the given conclusion.

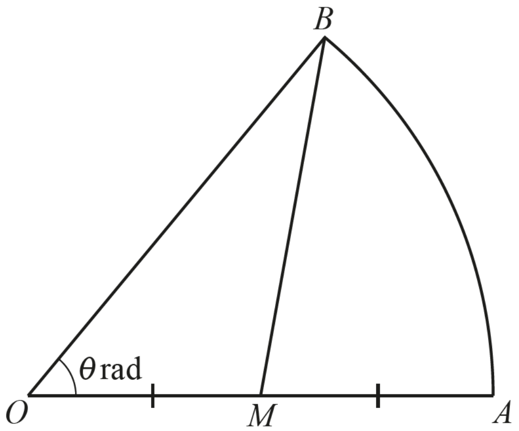
Question 9

9 Use the substitution $x = 2\sin\theta$ to show that $\int_1^{\sqrt{3}} \sqrt{4-x^2}\,dx = \frac{1}{3}\pi$. **[7]**

This proved to be a surprisingly challenging question, and the full range of marks was seen. The majority did attempt to use the given substitution, with only a few continuing to work in terms of *x*. Most appreciated the need to attempt the integrand in terms of *θ*, and attempted to do so. The most common errors were for an incorrect variable of *u* to be introduced, and for the simplification of the square root to be incorrect, with $\sqrt{(4 - 4\sin^2\theta)}$ becoming $2 - 2\sin\theta$. Of the candidates who did obtain the correct integrand, most were able to select the correct identity and then usually produced a fully correct solution.

Question 10 (a)

10

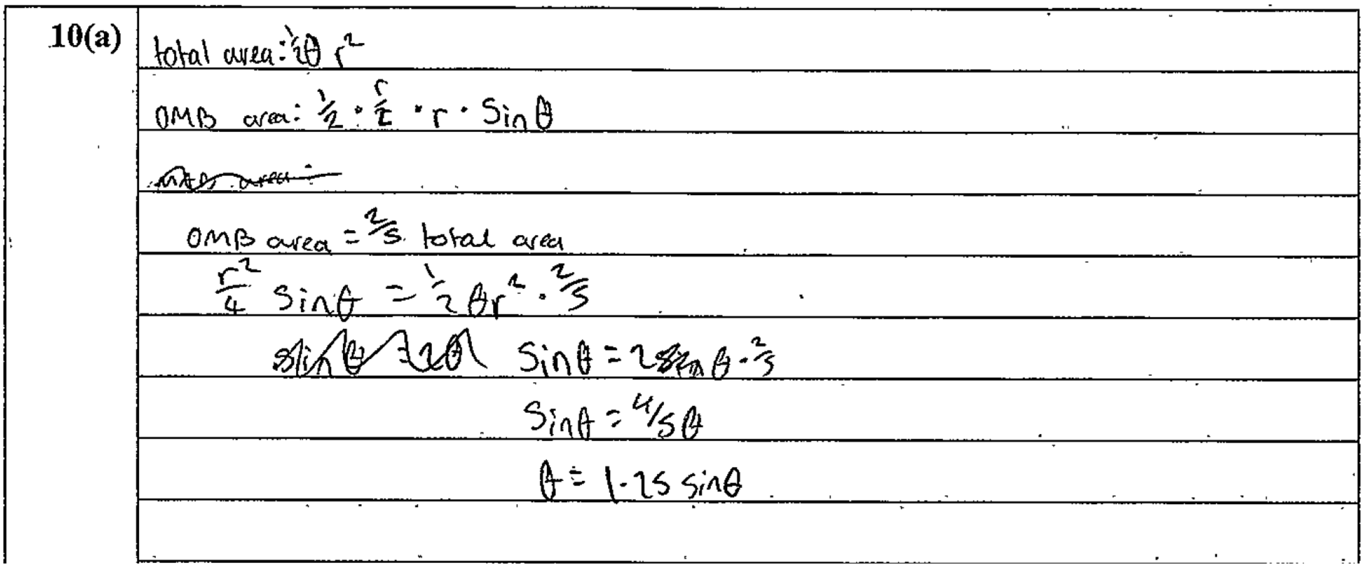


The diagram shows a sector *OAB* of a circle with centre *O* and radius *OA*. The angle *AOB* is *θ* radians. *M* is the mid-point of *OA*. The ratio of areas *OMB* : *MAB* is 2:3.

(a) Show that $\theta = 1.25\sin\theta$. **[4]**

This proved to be a challenging question, with over half of the candidates unable to state a correct expression for the area of triangle OMB. While most did attempt to use 0.5absinC, the most common errors were to use a = b = r, or to use a = OB and b = OM but never obtain an expression in just a single variable. Of those who obtained two correct areas, most could attempt to use the relevant ratio although this was sometimes the wrong way around. A lack of explanation, and too many steps being undertaken in one line of working, did sometimes result in solutions that were not entirely convincing.

Exemplar 3



10(a)

total area: $\frac{1}{2}\theta r^2$

OMB area: $\frac{1}{2} \cdot \frac{r}{2} \cdot r \cdot \sin\theta$

OMB area $= \frac{2}{5}$ total area

$\frac{r^2}{4} \sin\theta = \frac{1}{2}\theta r^2 \cdot \frac{2}{5}$

$\sin\theta = 2\theta \cdot \frac{2}{5}$

$\sin\theta = \frac{4}{5}\theta$

$\theta = 1.25 \sin\theta$

Both correct areas are stated, then the candidate makes it clear how the ratio is being applied. Here is sufficient detail before the given answer appears.

Question 10 (b)

The equation $\theta = 1.25\sin\theta$ has only one root for $\theta > 0$.

(b) This root can be found by using the iterative formula $\theta_{n+1} = 1.25\sin\theta_n$ with a starting value of $\theta_1 = 0.5$.

- Write down the values of θ_2, θ_3 and θ_4.
- Hence find the value of this root correct to **3** significant figures. **[3]**

This part of the question was very well done, with many fully correct solutions seen. Examiners expected to see the root given to 3 significant figures, and a clear indication that this was a value for the root and not just their final iterate.

Question 10 (c)

(c) The diagram in the Printed Answer Booklet shows the graph of $y = 1.25\sin\theta$, for $0 \leqslant \theta \leqslant \pi$.

- Use this diagram to show how the iterative process used in **(b)** converges to this root.
- State the type of convergence. **[3]**

Many candidates did not seem familiar with how the iteration was converging to the root, neither being able to identify 'staircase' nor drawing an appropriate diagram. The mark for 'staircase' was independent of the other 2 marks, and candidates should have been able to deduce this from the pattern of iterates in the previous part of the question. When using the diagram, the first step was to draw the line $y = \theta$, and then show clear detail of the pattern of convergence, whereas some diagrams had a staircase pattern but no straight line. A common error was to not give due consideration to approximately where the root would be on the diagram; a number of candidates assumed that it was at the stationary point on the curve, and others went beyond this.

Question 10 (d)

(d) Draw a suitable diagram to show why using an iterative process with the formula $\theta_{n+1} = \sin^{-1}(0.8\theta_n)$ does not converge to the root found in **(b)**. **[2]**

Some candidates could provide the correct shape for the arcsin graph, and less than half of those could then use it to show divergence from the root.

Question 11 (a)

11 The gradient function of a curve is given by $\dfrac{dy}{dx} = \dfrac{3x^2 \ln x}{e^{3y}}$.

The curve passes through the point (e, 1).

(a) Find the equation of this curve, giving your answer in the form $e^{3y} = f(x)$. **[6]**

Most candidates appreciated the need to separate the variables and could make a reasonable attempt to do so. The integration of the exponential term was usually correct. While integration by parts was often attempted on $3x^2\ln x$, the parts and/or the formula were not always correct. The latter is surprising as it is given in the list of formulae at the start of the paper. As long as there had been some attempt to integrate both sides, there was a mark available for attempting to use the given point of (e, 1) and many candidates did indeed gain this mark.

Question 11 (b)

(b) Show that, when $x = e^2$, the y-coordinate of this curve can be written as $y = a + \frac{1}{3}\ln(be^3 + c)$, where a, b and c are constants to be determined. **[3]**

Many candidates were able to make an attempt to use $x = e^2$, and simplify the ensuing expression which did require a term involving ln to still be present. Rearranging the expression to the given form proved to be more challenging and only the more astute candidates were able to attempt this, either by splitting into the sum of two terms or by taking out a factor of e^3 and combining this with the exponential term.

Question 12 (a)

12 A curve has parametric equations $x = \frac{1}{t}$, $y = 2t$. The point P is $\left(\frac{1}{p}, 2p\right)$.

(a) Show that the equation of the tangent at P can be written as $y = -2p^2x + 4p$. **[4]**

The majority of candidates gained full marks on this part of the question, and it was only a small minority that made no progress. The first 2 marks could be gained by finding a correct expression for the gradient, either in terms of *t* or *p*. Most candidates could then attempt the equation of the tangent, but a number struggled to use the same parameter consistently. With a given answer, there is an expectation that method is clearly shown, and most candidates did so.

Question 12 (b)

The tangent to this curve at P crosses the x-axis at the point A and the normal to this curve at P crosses the x-axis at the point B.

(b) Show that the ratio $PA:PB$ is $1:2p^2$. **[8]**

This proved to be a suitable challenging end to the paper, and fully correct solutions were in the minority. A number of candidates made no attempt at all at this part of the question, although it was unclear whether they were lacking inspiration or had run out of time. Of the remainder, most were able to make a reasonable attempt at finding the coordinates of *A* and *B*, though a number struggled with the algebraic manipulation required. Some candidates did not realise that it was the ratio of lengths that was required, and made no progress on the final 3 marks. When attempting the ratio, some candidates simplified both surds to a common factor, others attempted a division or demonstrated the veracity of the given answer, all with convincing use of algebra.

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