Oxford Cambridge and RSA

GCE

Mathematics (MEI)

Advanced GCE A2 7895-8

Advanced Subsidiary GCE AS 3895-8

OCR Report to Centres June 2015

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This report on the examination provides information on the performance of candidates which it is hoped will be useful to teachers in their preparation of candidates for future examinations. It is intended to be constructive and informative and to promote better understanding of the specification content, of the operation of the scheme of assessment and of the application of assessment criteria.

Reports should be read in conjunction with the published question papers and mark schemes for the examination.

OCR will not enter into any discussion or correspondence in connection with this report.

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4751 Introduction to Advanced Mathematics (C1)

General Comments:

Candidates now have a whole year to prepare for this examination. As last June, the first year in which there was no January examination, examiners found that many candidates were confident in applying the skills needed for this unit. For instance, greater familiarity with the circle equation meant that finding the intersections of a circle with the axes was done better than it used to be in some sessions. Candidates found most of the questions accessible, with most attempting all parts. Questions that were found most difficult were q9 and 12(i) and (iii).

Candidates' arithmetic skills without a calculator remain variable however, and many errors were seen in coping with fractions (questions 3 and 5 particularly) and multiplying in question 7; and in coping with negatives/subtraction in several questions such as 8(i), 11(iii) and 12(i).

Comments on Individual Questions:

Section A

Question 1

This proved to be a routine, straight-forward question for the majority of the candidates who were familiar with the topic of rearranging to make a different variable the subject of a formula. When only one of the two marks was awarded, it was often due to candidates not realising that the question specifically stated that $r > 0$ and so some gave an answer involving +/-. Occasionally this mark was awarded on the follow through for those candidates who correctly took the positive square root of their (incorrect) expression for r^2. Triple decker fractions were occasionally seen, which did not earn full marks if left in the final answer. A handful of candidates did not make their square root symbol long enough to cover both the numerator and denominator; very few candidates used a power of half, which would have made this particular issue obsolete.

Question 2

The majority of candidates correctly found the equation of the line and went on to find the intersection points as coordinates with the axes. A number of candidates used a perpendicular gradient (of $-\frac{1}{4}$) for their line and a number had issues when simplifying $y - 6 = 4(x + 1)$ or when substituting $(-1, 6)$ into $y = 4x + c$, but usually the first three marks were routinely obtained. Unfortunately a number of candidates did not realise that the question still had a further two demands and finished with stating that $y = 4x + 10$. Of those that did find the intersections nearly all correctly stated (0, 10) or $y = 10$ with the most common error being an x-intercept of 10/4 (instead of the correct −10/4). On those rare occasions when the first 3 marks were not awarded then the last two marks were usually earned on the follow through. Very occasionally candidates incorrectly combined their x and y values into a single coordinate.

Question 3

Nearly all candidates interpreted the zero power correctly in the first part. Many correct answers were seen in the second part, but not all could cope with the combination of a negative fractional power and a fraction. Notable errors were inverting the fraction whilst losing the power altogether (or losing it from either the numerator or denominator – so giving an answer of 9/5 or 3/25). A number of candidates left their answer as a triple-decker fraction. Decimal equivalent and +/- were rarely seen.

Question 4

The majority of candidates found this question on solving a linear inequality to be straightforward with nearly all scoring at least two of three marks available. Nearly all candidates started by correctly multiplying up by 7 to remove the fraction, although some made errors in doing so, such as $4x - 5 > 14x + 1$, $28x - 35 > 2x + 1$ or $28x - 35 > 14x + 7$. Usually the rearrangement was then done so that the $10x$ term appeared on the right already positive (so $-12 > 10x$) and in this situation the vast majority of candidates went on to get the correct answer. However, when candidates arranged to $-10x > 12$, a number neglected to reverse the inequality sign when dividing by the negative value of 10. Some candidates replaced the inequality sign with an equals, and used this throughout until a final statement – the method marks for multiplying and rearrangement were still available for such candidates.

Question 5

Again this was a good source of marks for the majority of candidates who found the demand of solving a pair of simultaneous equations relatively straightforward. x was usually found first, mostly through substitution of one equation into the other. Those who did use substitution and wrote down $x + 3(5x - 2) = 8$ nearly always went on to get the correct answer for x – although it was disheartening to see the number of times that $16x = 14$ became $x = 16/14$. Those that did have x correct usually went on to find y correctly as well although some candidates, as is always the case in this type of problem, moved on and forgot to find the other value, and some had difficulty in coping with the fractions. Those who substituted for y and had $y = 5(8 - 3y) - 2$ were usually less successful due to the number of negative terms in the equation. Elimination methods were less frequently seen and not as successful – candidates often did not multiply all values by the required constant or they added or subtracted their pair of equations incorrectly.

Question 6

Many candidates gained all three marks in the first part, with the most common error being wrong evaluation of the term $4\sqrt{5} \times \left(-2\sqrt{5}\right)$. The second part was found much more difficult. Many candidates reached $\sqrt{72} = 6\sqrt{2}$ but were unable to combine that correctly with $\frac{32}{\sqrt{2}}$, either not rationalising the denominator of this correctly or often by multiplying both terms by $\sqrt{2}$ with no appreciation that they would then need to divide the resulting 44 by $\sqrt{2}$.

Question 7

Quite a few candidates gained full marks for this binomial expansion. A fair few candidates struggled to cope with the arithmetic, making errors in the calculation of the coefficients, despite demonstrating good understanding of the binomial expansion in their working. Some failed to raise the 3 to the various powers, though usually the −2 was dealt with correctly. Occasionally candidates attempted to take out a factor of three, but some failed to realise that this should lead to a factor of 3^4 outside the bracket.

Question 8

Fewer candidates gained all five marks on this question than in the earlier questions in the paper. In the first part, the most common error was to omit brackets with the $3x^2$ term, though this was often corrected to $9x^2$ in the next line. Another common mistake was to make sign errors when removing brackets from $9x^2 - (4x^2 + 4x + 1)$. Had the answer not been given in the question we might have seen more of these, as there was evidence that some candidates corrected themselves by changing + signs to − signs! It was also quite common to see no mention of h^2 until stating the given result, sometimes with no correct Pythagoras statement given at any point. In part (ii), most reached $5x^2 - 4x - 8 = 0$, though it was not uncommon for the '= 0' to be omitted. A few did not cope correctly with the information $h = \sqrt{7}$ and a few failed to rearrange the equation correctly into an appropriate form. Most correctly substituted into the quadratic formula, with only a small number of candidates not remembering this formula correctly. However, it was extremely common for the final mark to be lost for giving 2 answers and not recognising the need to give the positive solution.

Question 9

Most candidates gained the mark for correcting the symbol in the statement in the first part. However, there were a fair number who did not use the correct notation and wrote e.g. $\rightarrow$ or ⇨, in spite of the fact that the correct symbols to use were given in the question. Explanations as to why $\Leftarrow$ was not appropriate were often either incorrect or insufficient. Many thought that a rectangle's diagonals intersect at 90°(or those of a parallelogram or a trapezium), and some appeared not to realise that diagonals were being considered and talked about the internal angles in a rectangle being 90^0. Others did not go far enough to get the mark, just saying that a square is not the only quadrilateral that has diagonals intersecting at 90^0, without giving any example. Correct answers usually mentioned a kite, a rhombus or a diamond as having this property, some with a supporting sketch. A few spoiled their answer by including a rectangle along with the kite or rhombus. In the second part, a common error was to think that the correct symbol was $\Leftrightarrow$, thinking that the square of a non-integer was also a non-integer. Some candidates thought that negative whole numbers were not integers. Usually a correct answer was supported by a numeric example of a surd for *x*, though a small number mentioned decimals.

Section B

Question 10

(i) Most candidates had the general shape of the cubic curve correct in their sketch, although some tended to lessen the gradient at the ends so that their curves appeared to approach further turning points. The most common error was to omit the y-intercept.

(ii) Most candidates gained both marks in correctly expanding the factorised form. The few errors were usually in getting the sign of a term wrong or occasionally being careless in writing a power, e.g. writing 4x2 instead of 4x3 in the final answer. Candidates who attempted to expand all three brackets at once were sometimes successful but this approach was more prone to errors than expanding two brackets as a first step.

(iii) Many candidates lost a mark by not using the word translation. Some gave wrong answers such as a double negative 'move down by −36'. Sometimes candidates gave conflicting answers such as 'move by 36 in the *y*-direction' as well as $\begin{pmatrix} 0 \\ -36 \end{pmatrix}$.

(iv) This part was well done, with many candidates gaining full marks. A few did not show explicitly that g(−1) = 0, although nearly all correctly used the fact to attempt further work using (x + 1) as a factor, with only a few attempted divisions by (x – 1) being seen. Most candidates seem well-practiced at division, with most using long division but a substantial minority using inspection. A few candidates failed to factorise the quadratic factor correctly. A few weak candidates only showed that g(−1) = 0, but then did not know how to proceed.

Question 11

(i) The centre and radius were usually given correctly.

(ii) Many began by substituting (21, 0) into the circle equation and showed that the left-hand side equalled 125. Few used a diagram and a direct application of Pythagoras' Theorem. They could then use symmetry to find the coordinates of A, but many did not. The other method was to put y = 0 into the circle equation and solve the ensuing quadratic to obtain both B and A. This was nearly always the method used with x = 0 to find D and E. A few candidates did not know how to proceed, but the majority gained most, if not all the marks in this part.

(iii) Most candidates started correctly in finding the gradient of BE, although this was sometimes wrongly simplified. Some wasted time by finding the equation of BE before realising they needed the perpendicular gradient. It was quite common then to use the coordinates of C to find the equation through C, which was perpendicular to BE, without showing it was the perpendicular bisector (this gained 4 of the 6 marks). Those who approached by finding the midpoint of BE and the equation of the perpendicular bisector and showed that C was on it were often successful in gaining all 6 marks – indeed some were able to find previous errors in their working during this process. Some candidates assumed that C was the midpoint of BE and began by finding the gradient of BC and its perpendicular, which gained no marks.

Question 12

(i) Many candidates struggled to earn more than the first one or two marks with some stopping at 3x2 + 10x + 13 = k and trying to work with the left and side of this equation. The presentation of answers in this part was variable as candidates tried various methods to make progress. Those who went for the more obvious approach of working with the discriminant of the correct equation were often successful – earning 4 or 5 marks (though sign errors were commonplace in these attempts). Those few who attempted methods based on completing the square often made errors, but also achieved some success – generally scoring around 3 marks. Those who used the quadratic formula on the correct equation sometimes confused themselves and stated that it was > 0 rather than the discriminant was > 0. Errors with inequalities were also fairly frequent in this part. Occasionally, attempts using calculus were seen and these also scored reasonably well and were credited, even though not expected in this module.

(ii) Most candidates earned at least 2 marks in their attempts at completing the square – usually for at least having a and b correct. Many candidates were unsuccessful in finding c, as they did not deal with the factor of 3 successfully, with a common wrong answer being c = 9 instead of the correct 1, although a few earned the method mark for 13 − 3 × their b2 or for 13/3 − their b2 – with the latter mark often being awarded for sight of 1/3. Those who expanded 3(x + 2)2 and then realised that all that was required was to add 1 were very successful. A few candidates multiplied out a(x + b)2 + c and then compared coefficients. For the last mark, many were successful in giving a correct or correct follow-through reason for the graph being above the x- axis. However many more simply evaluated a discriminant and, finding it was negative, concluded that the graph was above the x-axis – without giving any extra information to confirm that it was indeed above and not below the axis.

(iii) It was quite frequent for at least a mark to be earned here for the substitution of their minimum point coordinates into the line, although this also required a correct interpretation of their completed square form of the equation. Some candidates found the minimum point using calculus in this part – rather than using their vertex form found in part (ii). For some this was of benefit, as they found the correct point. It was a shame that of these, those who were incorrect in (ii) did not realise their error and revisit that part to correct it. Some totally ignored the *y*-coordinate and equated the equations of the line and curve, then only needing to have a correct *x*-coordinate – generally those who did this were correct in their solutions.

4752 Concepts for Advanced Mathematics (C2)

General Comments:

The paper was accessible to the majority of candidates, and most seemed well-prepared. A significant minority of candidates demonstrated a fair degree of understanding of Core 2 syllabus material, but failed to do themselves justice in the examination because of poor (GCSE level) algebra, careless arithmetical slips and failing to read the question correctly. Premature approximation followed by over-specification of final answers also cost some candidates easy marks.

Most candidates presented their work neatly and clearly, but in some cases work was very difficult to follow, and candidates should understand the importance of presenting a clear mathematical argument, especially when there is a “show that” request in the question.

The handing out of 16 page answer booklets to candidates who need extra space is unhelpful: often only one page is used.

It is disappointing to see some candidates misquoting formulae that are given to them in the booklet, notably in question 4.

Centres are advised that using a graphical calculator to avoid a demand to use calculus, for example in question 5, or to solve an equation for example in question 7 will earn no credit unless the relevant working is presented.

Comments on Individual Questions

Question 1

Part (i)

This was done well. A small minority of candidates failed to score: most problems were caused by a failure to put the original function into index form correctly.

Part (ii)

A few candidates differentiated or tried to integrate both the numerator and the denominator independently, but most knew what to do here and went on to score 2 or 3 marks. A significant minority of candidates neglected to add ‘+ c’, thereby losing an easy mark.

Question 2

A little under half of candidates achieved full marks on this question. Approximately 20% prematurely rounded their answers and lost the final accuracy mark, and a few found the sum of the second to fifth terms inclusive instead of the first to fourth. The most common error for those who failed to score at all was to treat the sequence as being defined algebraically, but a few candidates misused the formula for the sum of an arithmetic or geometric progression.

Question 3

Most candidates knew what to do here, but a surprisingly high number misread “fiftieth” as “fifteenth”, and a few misread “fiftieth” as “fifth”. A few then also misread one of the numbers. However, most read fifty correctly. The majority went on to solve their equations successfully, but a surprising number obtained a positive value for d and simply carried on, without stopping to think that this could not possibly be correct. Candidates would to well to ask themselves whether or not their answer is sensible in the context of the original question. It seemed that many candidates simply didn’t see the request to find the sum of the first fifty terms, and stopped after finding a and d.

Question 4

This was very well done: approximately two thirds of candidates obtained full marks. Some candidates converted to degrees and lost the accuracy marks and a few candidates used incorrect formulae.

Question 5

The majority of candidates differentiated successfully and went on to identify $\pm\sqrt{2}$ correctly. A few neglected the negative root, losing an easy mark. Thereafter candidates went astray in a variety of ways. Many candidates used incorrect forms when writing their inequalities. $x > \pm\sqrt{2}$ was seen frequently and many candidates combined their separate inequalities in illegal ways such as $\sqrt{2} < x < -\sqrt{2}$. These candidates were penalised if the correct inequalities were not seen first. Candidates should realise that it is good practise to write the two inequalities separately first, before any attempt is made to combine them. Some candidates decimalised $\pm\sqrt{2}$ were penalised for having a slight inaccuracy in their answer.

A few candidates didn't differentiate at all, thereby ignoring the instruction to use calculus and so made no progress.

Question 6

Part (i)

A small number of candidates drew two curves of totally different shapes, which was surprising, but most knew the correct shape and although many sketches were sloppily presented, and marks were lost through omitting to identify (0, 1) or by allowing the curves to coalesce through the second quadrant.

Part (ii)

This was very well done. Nearly all candidates correctly found $x = 3$; a few then evaluated 3^3 as 6, 9 or 81.

Question 7

A few candidates were unable to eliminate $\sin^2\theta$ legitimately, but all bar the weakest candidates managed at least 2 marks here. A small number of candidates made errors when rearranging to zero – generally with the constant term.

Some were using x for $\cos x$ in their quadratic formula and not recovering the 'cos'. This was unfortunate. Candidates must realise that this is not a useful practice. Even those who made other substitutions often failed to give their evaluated formula a subject and then confused themselves.

Some candidates resorted to rounded decimals very quickly and made premature approximation errors in their answers, thus losing one or more accuracy mark.

Quite a few candidates were finding the second angle by adding 0.66 to 1.5π rather than subtracting it from 2π.

A fair number of candidates worked in degrees – a good number of these were allowed the SC1 for a pair of correct answers. When the question stipulates angles over a range such as "between 0 and 2π", the expectation is that their angles will be in radians, not degrees.

Question 8

A minority of candidates found this question straightforward and produced fully correct solutions. However, the majority struggled or failed to give sufficient detail of their working to earn full credit.

A good number found the gradient of the line as 3. Some used $\frac{\log 6}{\log 2}$, indicating the common misconception of the model. log$y$ = 3log$x$ + log 2 was very common as a second statement. Those who earned the second mark very often lost the third for statements such as y = 3x + 2 (removing all the "logs") or $y = x^3 + 100$, without log$y$ = logx^3 + 2, or equivalent, having been seen. It is important that each step should be shown as correct final answers were often seen following incorrect working, which of course do not score.

A few candidates knew that the final model was of the form $y = ax^b$ and also demonstrated that b was the gradient and a was $10^{\text{(the intercept)}}$, producing the correct equation relating y and x. Many of these candidates would have done better to re-read the question as most of them omitted to state the equation relating log$y$ and log$x$, which was one of the demands of the question.

Question 9

Part (i)

Most candidates used the Cosine rule correctly to calculate angle A and most went on to calculate the area correctly using ½absinC. A minority complicated matters by splitting the triangle into 2 right angle triangles, calculating the height and then using Pythagoras to calculate the base of each triangle and hence the area of each separately. A few candidates unnecessarily found one of the other angles and then used ½absinC. In both cases this usually resulted in a loss of accuracy so their final answer was outside the permissible range. Similarly, some candidates rounded their value for cos$A$ and went on to lose both accuracy marks. Approximately three quarters of candidates scored full marks.

Part (ii)

Most candidates used the trapezium rule separately for the upper and lower areas, with a smaller number recognising that the total area could be calculated with a single application. The most common error was omitting the outside pair of brackets in the formula and this was rarely recovered. Another common error was the failure to recognise that the absolute areas should be summed, with candidates subtracting the lower area from the upper. A surprising error for several candidates was getting the value of h incorrect as this was not only clear from the table, but also explicitly stated in the question. Nevertheless, a significant majority scored full marks.

Question 10

Part (i)

The majority of candidates gained full marks on this question. A few found the gradient correctly and then went on to find the equation of the normal, and some candidates integrated and found the equation of the curve.

Part (ii)

Most candidates integrated successfully. A few omitted '+ c' and made little progress thereafter, but the majority successfully obtained the equation of the curve. Many candidates failed to give the co-ordinates in a correct form or transposed the signs, thus losing an accuracy mark. Most candidates used the given derivative to find the co-ordinates of the minimum point, but it was surprising how many made a sign error and then couldn't obtain the correct value for y. A significant number of candidates completed the square instead of using the derivative, and most lost accuracy.

Part (iii)

Very few candidates realised that they needed to work with f(2*x*) to find the new equation. The majority of those who did adopt the correct approach often went wrong, usually with the first term. In order to earn the method mark by this approach examiners needed to see the substitution: many candidates just wrote down $y = 4x^2 + 6x - 5$ and failed to score. It may have been the case that the correct approach was being attempted, but this answer was also seen resulting from totally wrong working!

A few candidates successfully worked with the images of the intercepts following the stretch, but often failed to simplify the answer correctly.

A minority of candidates earned the third mark, either as a follow through mark or for a fully correct answer. However, many candidates multiplied the *x* value by 2, or halved the *y* value instead or as well.

Question 11

Part (i)

Many candidates found this a straightforward question and answered it successfully. 3×3^7 or 3^8 was frequently seen as the method. 1×3^7 was seen occasionally as was an unsupported 2187. Many candidates opted for longer methods, which included lists of powers of 3 and/or diagrams.

Part (ii)

This was answered successfully by the majority of the candidates, including those who simply worked out the terms of the GP and added them. Stronger candidates achieved a correct answer from a correct formula although there was a good number of unsupported correct answers. A variety of incorrect formulae were in evidence, among the more common were: $\frac{1(3^{15}-1)}{3-1}$, $\frac{3(3^{14}-1)}{3-1}$. and $\frac{3(3^{15}-1)}{15-1}$

Many candidates listed the terms either evaluated or expressed as powers and summed their list to achieve a correct result.

Part (iii)

This part differentiated well between the best and good candidates. Setting up the initial inequality proved beyond many, even those who had successfully used the formula for the sum of a GP in part (ii). There were some splendid examples of well-argued proofs, but getting beyond the first M1 was unusual. Those who started with the $1-3^n$ version of the formula were rarely successful, as basic rules of inequalities when multiplying by a negative were forgotten. Some candidates also thought that $3 \times 3^n = 9^n$. The taking of logs produced problems. Sadly, many candidates who managed to get started with the inequality, didn't answer the last part, whereas weak candidates often went straight for this. A surprising number of candidates thought it perfectly reasonable to have non-integer numbers of generations.

Part (iv)

Those candidates who answered parts (i) and (ii) successfully usually went on to achieve full marks in part (iv). A few worked with the fifteenth term, rather than the sum of the first fifteen terms.

4753 Methods for Advanced Mathematics (C3 Written Examination)

General Comments

The performance of candidates was similar and comparable to recent papers. There were many excellent scripts, showing sound preparation, good presentation, and accurate mathematics. The mean mark for the paper was very similar to last year's, though there were one or two quite demanding marks which meant there were fewer candidates who gained full marks. At the lower end, there were very few candidates who scored fewer than 25 marks. There was also very little evidence of candidates running out of time, and most answered all the questions.

More successful candidates have the experience to select appropriate methods. There is perhaps a danger that students are too eager to apply newly-taught methods, for example integration by substitution or parts, instead of more basic ones, such as expanding brackets and integrating term-by-term. This was evident in the number of students who lost marks for the integrations in 8(ii) and 9(iii). Conversely, they need to know when **not** to expand brackets, such as when finding the inverse function in 9(iv)!

Quite a few candidates used additional sheets – perhaps more space should have been allowed for some questions, such as 8(ii). However, it is helpful if centres avoid using 12-page additional booklets unless they are actually necessary, as all the pages have to be scanned and then checked and annotated.

Comments on Individual Questions

Section A

1. The product rule was done well, and most candidates were successful in arriving at tan x = 2 at the turning point. The most common error was to give x in degrees and then to use this to calculate y, giving a rather alarmingly large result!

2. This question was also answered well, either using substitution or by inspection. However, a surprising number of candidates who substituted left their final answer in terms of u, and a few lost the final mark through omitting the arbitrary constant.

3. There was a pleasing response to this question. Integration by parts was well understood by the majority of candidates, many of whom gained full marks. Very occasionally, u and v' were allocated to the wrong parts, and the other most common error was failing to simplify v u' before integrating this.

4. This question was less well done. Nearly all candidates gained marks for quoting a correct chain rule and using dV/dt = 5. By far the most common error thereafter was to fail to find V as a function of h and instead differentiating $V = \pi r^2 h/3$ to give $dV/dh = \pi r^2/3$. Even when candidates recognised the need to substitute for r, there were a surprising number of trigonometric errors, such as h = r sin 45°. A number of solutions which found dh/dt = 1/20π then went on to write or evaluate this as π/20.

5. Implicit differentiation was well understood, although differentiating the '2xlny' term using the product rule defeated some candidates, and there were some algebraic slips in re-arranging to find dy/dx (which virtually all candidates did before substituting x = 1 and y = 1).

6(i) This was an easy two marks for virtually all candidates, though occasionally they left their answer as sin π/6 without evaluating this as ½.

6(ii) This part was the polar opposite of part (i), with very few candidates getting anywhere. Two common errors were to infer that sin x = cos x and therefore x = $\pi/4$, and dividing arc sin x by arc cosx to get arc tan x. Successful candidates usually introduced another variable y equal to arc sin x, so that sin y = cos y, tan y = 1, y = $\pi/4$, and x = sin $\pi/4 = 1/\sqrt{2}$.

7(i) Most candidates gained a method mark for substituting (1-x)/(1+x) for x in f(x). However, the simplification of the ensuing algebraic fraction proved to be problematic to many candidates, who failed to clear the subsidiary denominators correctly. Concluding that f-1(x) = f(x) should of course be a 'write down' from ff(x) = x; however, virtually all candidates found f-1(x) by rearranging the formula for x = f(y), usually correctly. Occasionally we were offered f-1(x) = 1/f(x) = (1+x)/(1-x).

7(ii) This was well answered, with few candidates using particular values of x to 'show' that g(x) was even. We condoned the use of f instead of g. Occasionally the brackets were misplaced in 1 – (-x)2 or 1 + (-x)2. The geometrical interpretation was well answered: although we would prefer 'symmetrical about the y-axis' to formulations such as 'reflection in the y-axis', the latter was nevertheless condoned.

Section B

8(i) This part was very well-answered, with many getting all 7 marks. The majority of candidates opted to use the quotient rule rather than the slightly easier method of expanding the numerator and dividing through by x. Even so, provided they took care in the use of brackets, they gained the first three marks. The second part was not quite as successful. Some candidates forgot to work out the y-coordinate of Q; others got the second derivative wrong, or failing to state explicitly that for a maximum the second derivative was negative.

8(ii) Most candidates verified that y = 1 when x = 1 or 4, though the majority did this by re-arranging the equation $(x - 2)^2 = x$ as a quadratic and solving this. However, for the integration, many candidates failed to spot the need to expand the $(x – 2)^2$ term and divide through by x, and most attempts to use substitution (except perhaps for the somewhat fatuous u = x) or parts usually led nowhere. Those who managed this integration successfully often failed to realise they then had to subtract this value from the area of the rectangle, or did this subtraction the wrong way round. Quite a few also calculated the area of the rectangle as 4 × 1 = 4 instead of 3.

8(iii) Fewer than half of the candidates gained full marks for this part of the question. Many did not know how the translation would affect the function algebraically, for example starting with y - 1 = f(x + 1). Of those who derived a correct expression for g(x), many failed to incorporate the '−1' into their fraction.

8(iv) Very few candidates scored both marks here. A method mark was awarded if their answer indicated recognising the translation of their area from part (ii); but few of those who got part (ii) correct realised that the integral would be the negative of this as the transformed area is below the axis.

9(i) Most candidates succeeded in finding x = ln 3, either by square rooting or solving the quadratic in e^x. The second method was somewhat compromised by setting $x = e^x$ (rather than a different variable) to get a quadratic in x, though we condoned this for both marks.

9(ii) This provided a simple four marks for most candidates, using a chain rule to find the derivative, setting this to zero and solving to get x = ln 2. A neat alternative method was to recognise that the $(e^x – 2)^2$ term must be non-negative and minimum when $e^x – 2 = 0$, or x = ln 2.

9(iii) This proved to be a rather costly part for candidates unless they recognised the requirement to multiply out $(e^x - 2)^2$ -1 to get $e^{2x} - 4e^x + 3$ and then integrate term-by-term. Other attempts using substitution or parts usually got nowhere. Although originally we required candidates to give the area as 4 – 3ln3, very few actually did this, so it was decided to condone a (negative) area of 3ln3 – 4.

9(iv) Rather more than half of the candidates managed the inverse function well, though a few made errors at the last stage of taking the square root, and concluded with $y = \ln(\sqrt{(x + 1)}) + 2$, or $y = \ln(\sqrt{(x + 1)} + \ln 2$. Some were perhaps encouraged by the previous part to multiply out $(e^x - 2)^2$ again, though they could still obtain a method mark for a step towards finding *y* in terms of *x*. It was not uncommon to see candidates taking logs of individual terms.

The domain and range required accurate use of notation (x = … for domain, y = … or $f^{-1}(x)$ = … for range, and ≥ for both); occasionally these were correct but in the wrong order, so that it was unclear which was which.

The graph proved to be quite demanding. The majority of candidates convinced us they were attempting to reflect some of the original curve in y = x and got a method mark. However, far fewer gained the ‘A’ mark by reflecting the correct part of the graph from (-1, ln 2) onwards, and identifying this point clearly in their sketch.

4754 Applications of Advanced Mathematics (C4)

General Comments

Candidates found Paper A more straightforward than in previous years and therefore the standard of work was very high. This paper was accessible to all candidates but there were sufficient questions for the more able candidates to show their skills.

Paper B, the comprehension, was well understood and most candidates scored good marks here.

Candidates made similar errors as in previous years and these included:

- Sign and basic algebraic errors (Question 1)
- Failure to include a constant of integration (Question 7(ii))
- Poor anti-logging and rules of logarithms (Questions 7(ii) and 7(iv))
- Failure to give clear descriptions in the comprehension paper (Questions 4 and 7)
- Inappropriate accuracy, for example in Question 2, candidates either gave insufficient accuracy (answers to the nearest integer) or they gave too much accuracy (answers to 4 or more decimal places) – candidates are reminded to give answers to 1 decimal place for questions involving trigonometry
- Failure to give exact answers when required (Question 5(iii))
- Failure to give sufficient detail when verifying given results (Questions 5(i), 5(ii), 6(i), 6(ii)(A), 7(ii), 7(iv))

Some candidates still assume that showing that a vector is perpendicular to one vector in the plane is sufficient to show that it is a normal vector.

Quite a number of candidates failed to attempt some parts but there did not appear to be a shortage of time for either Paper.

Centres are again reminded that as Papers A and B are marked separately any supplementary sheets used must be attached to the appropriate paper.

Comments on Individual Questions:

Paper A

Question 1

Common errors included:

- $5(x+1)-3(2x+1)=(2x+1)(x+1)$ (and not the correct $5x(x+1)-...$)
- Expanding $-3(2x+1)$ as either $-6x+3$ or $-6x-1$ or $-6x+1$
- There were some candidates who did not multiply up on the right-hand side and so obtained $5x(x+1)-3(2x+1)=1$
- Some lost the final two marks for not applying the quadratic formula correctly

However, this question was generally done well with most candidates scoring full marks and demonstrating sound basic algebraic manipulation skills. It was common to see the use of the quadratic formula as much as factorising to solve the final quadratic equation. Very few completed the square but those that did were mainly successful.

Question 2

The majority of candidates correctly replaced $\cos 2\theta$ with $1-2\sin^2\theta$ although a minority of candidates made the costly mistake of replacing $\cos 2\theta$ with $1-\sin^2\theta$. While some candidates struggled to factorise $12\sin^2\theta-\sin\theta-6=0$ many used the quadratic formula to solve this equation, and as with question 1, there were some candidates who did not state or apply the quadratic formula correctly. While the majority of candidates found the correct values for $\sin\theta$ some incorrectly obtained $-\frac{3}{4}$ and/or $\frac{2}{3}$. Of those candidates that obtained the correct values for $\sin\theta$ the majority went on to score full marks. However, it was fairly common to see '$\arcsin\left(-\frac{2}{3}\right)=-41.81...$ *therefore no solutions in the range'* with no appreciation that solutions in the correct range could be found from this value. Having found the principal values it was common for candidates to get the other solutions in the range, often sketching the sine curve to help them, though most did this correctly without demonstrating any method.

Question 3

The most common mistake in part (i) was to use a value of 2 rather than -2 as the coefficient of x in each term of the expansion. The binomial coefficients were nearly always correct though a small number missed the $2!$ from the denominator of the x^2 term. While the majority of candidates used the correct value of n a small minority incorrectly used $n=\frac{1}{3}$ or $-\frac{2}{3}$. The range of validity of the expansion was done much better than in previous years although the most common mistake was to give non-strict inequalities. Other mistakes included:

- $-\frac{1}{2}<-x<\frac{1}{2}$
- $|x|>\frac{1}{2}$
- $\frac{1}{2}<x<-\frac{1}{2}$

In part (ii) the majority of candidates correctly multiplied their answer from part (i) with $(1-3x)$ and simplified this expression correctly to obtain the correct values of a and b. It was concerning, however, that a number of candidates wrote $(1-3x)(1+\frac{2}{3}x+\frac{8}{9}x^2+...)=1+\frac{2}{3}x+\frac{8}{9}x^2-3x-2x-\frac{8}{3}x^2+...$ or even more worryingly expanded $(1-3x)^1$ as $1-3x+$ higher order terms in x.

Question 4

This question differentiated well due to the coefficient of $\sin x$ taking the form of a positive constant rather than a number. Many candidates, however, were unfazed by this and worked out the correct values for R and α. Some candidates lost the first method mark by not including R in the expanded trigonometric statements $R\cos\alpha=1, R\sin\alpha=\lambda$. Writing α in terms of the more complex $\arcsin$ and $\arccos$ expressions was surprisingly common.

It was a little worrying that a sizeable minority of candidates went from the correct $R=\sqrt{1+\lambda^2}$ to the incorrect $R=1+\lambda$, thinking the squared terms and the square root cancelled each other out.

In part (ii) those candidates that realised that $R=2$ usually went on to get the correct values for λ and α. However it was common for λ to be incorrect due to an incorrect expression for R from part (i). A fair proportion of candidates gave α in degrees and those who gave α as either $\arccos\left(\frac{1}{\sqrt{1+\lambda^2}}\right)$ or $\arcsin\left(\frac{\lambda}{\sqrt{1+\lambda^2}}\right)$ were generally less successful in this part than those who gave α as $\arctan\lambda$.

Question 5

In part (i) the majority of candidates correctly wrote down the result that $\frac{\mathrm{d}y}{\mathrm{d}x}=\frac{2\sec^2\theta}{\sec\theta\tan\theta}$. It was clear though that a significant number of candidates did not know that $\frac{\mathrm{d}}{\mathrm{d}\theta}(\tan\theta)=\sec^2\theta$, and the majority of these applied the quotient rule to $\frac{\sin\theta}{\cos\theta}$ in an attempt to derive this result. A significant minority of candidates did not show adequate working to gain the final mark in part (i) with many going directly from $\frac{2\sec\theta}{\tan\theta}$ (or equivalent) to the given answer. Candidates are reminded that in questions in which the demand is to show a given result then sufficient working must be shown to satisfy the examiner that the answer has been correctly derived and not simply written down. It was also noted by examiners that a number of candidates multiplied their expressions for $\frac{\mathrm{d}y}{\mathrm{d}\theta}$ and $\frac{\mathrm{d}x}{\mathrm{d}\theta}$ rather than dividing.

Although the techniques of verifying the Cartesian equation of the curve was relatively straightforward, answers in part (ii) were poorly presented, with many candidates unable to present a mathematical justification clearly and formally. Some candidates were insufficiently confident in the use of standard trigonometric identities and for some candidates it was as if they had never seen the relationship that $1+\tan^2\theta\equiv\sec^2\theta$.

In part (iii) the vast majority of candidates considered both the correct integral for the volume of revolution and integrated $4x^2-4$ correctly. It was the mention of a rotation of 180° that seemed to concern many candidates and a considerable number divided the correct answer of $\frac{16}{3}\pi$ by 2.

Question 6

There seemed to be a misconception amongst a number of candidates about the definition of ‘show’ and ‘verify’ in this first part. The majority of candidates correctly substituted the coordinates of A, B and E into the equation of the plane, to achieve the first two marks. Those candidates who tried to derive the equation of the plane had methods that were generally incomplete and despite a lot of work, did not gain much credit.

In part (ii)(A) a number of candidates seemed to think that just showing one direction vector was normal to the plane was sufficient and some candidates showed all three. It was unfortunate that so many lost marks by not showing the evaluation of the scalar product(s) even though this was another ‘show that’ question and so examiners had to be convinced that the candidates were indeed showing the required results and not simply stating them.

Part (ii)(B) was nearly always done correctly with only a small minority having the equation of the plane as $x-6y-6=0$ rather than the correct $x-6y+6=0$.

Part (ii)(C) occasionally contained simple arithmetical errors with the correct equation often leading to either $b = \frac{3}{4}$ or $b = -\frac{4}{3}$. Some candidates stated the direction vector $\overrightarrow{\mathrm{FG}}$ correctly and then either did not state the length of FG or resorted to using Pythagoras to calculate this length, not recognising that they could simply read off the required answer.

To find the angle EFB in part (iii) most candidates attempted to find vectors (and hence use the scalar product) that would lead to the correct angle, though there were common arithmetical errors here.

Some candidates used $\overrightarrow{\mathrm{EF}} \bullet \overrightarrow{\mathrm{FB}}$ and hence obtained an acute angle, often not recognising that they needed to subtract this from 180° as angle EFB was obtuse. Some candidates who used $\overrightarrow{\mathrm{FE}}$ and $\overrightarrow{\mathrm{FB}}$ 'lost' the minus sign in their calculation and ended up with an answer of 36.9°. A very small number of candidates calculated the lengths of the three sides of triangle EFB and used the cosine rule.

Part (iv) required candidates to find the height of Q above the ground. Those candidates who thought the $y-$ axis represented the vertical height clearly did not look at the diagram carefully enough. A surprising number of candidates could not calculate the z coordinate of P correctly. Some candidates seemed to think that in finding $\overrightarrow{\mathrm{PQ}}$ they had arrived at the required answer whereas other candidates worked out the direct distance from the origin to point Q. Too many candidates worked out both the x and y coordinates of Q when only the z coordinate was required. Finally, a number of candidates found the correct position vector for Q but did not explicitly state the height of Q above the ground.

Question 7

Part (i) was answered extremely well with nearly all candidates correctly expressing $\frac{1}{(1+2x)(1-x)}$ in partial fractions.

In part (ii) the majority of candidates were able to separate the variables and substitute their partial fractions correctly. There were, however, frequent errors in the integration usually when candidates forgot to divide by 2 when integrating $\frac{1}{1+2x}$ and/or when they forgot to do the same process with the -1 when integrating $\frac{1}{1-x}$. Many candidates did not include a constant of integration or, if included, it was either subsequently ignored or set to zero without any mathematical justification. Most candidates were able to combine their logarithmic terms correctly, though examiners noted the high volume of cases in which the 'correct' printed answer was seen following earlier incorrect working.

Most candidates achieved the first two marks in part (iii) for finding the value of k, but many made errors in handling the logarithms to find the time taken for the drug concentration to reach 90% of its maximum value. Examiners noted the large variation in the accuracy of candidates' final answers in this part.

In part (iv) most candidates multiplied up by $1-x$, collected and factorised the x terms correctly. The main problem seemed to be how to get the negative exponent. These often appeared when candidates divided $e^{3kt}-1$ by $2+e^{3kt}$, losing the final accuracy mark in the process. It was also common for candidates to simply not show how $\frac{e^{3kt}-1}{2+e^{3kt}}$ was equal to the given answer. Those candidates who started by taking the reciprocal of the answer given in part (ii) were usually far more successful in deriving the required result in this part. The majority of candidates who attempted to verify that the drug concentration approached its maximum value in the long term recognised that as $t \to \infty, \mathrm{e}^{-3kt} \to 0$, although some candidates simply substituted a large value of t to show that x was close to 1, this approach was not sufficient to earn the final mark in this part.

Paper B

Question 1

Most candidates scored all three marks.

Question 2

While the vast majority gave the correct answer as a percentage a number of candidates left their answer as a decimal. The most common errors included numerators that were not equal to 110 (the most common incorrect values being either 90 or 95 or 125) and/or denominators that were not equal to 146.

Question 3

This part was nearly always answered correctly although the question did specifically asked for an answer to 2 decimal places and a significant number of candidates gave an answer of only 5.2. A smaller minority forgot the factor of 10 giving an answer of 0.52.

Question 4

Candidates found this part relatively demanding with very few fully explaining how the figure of 188 seconds had been derived. While many candidates gave a correct calculation (and so scored the first mark) many did not give an accurate and correct justification for their calculation. Many candidates who gave the departure time of 164 seconds did not make it explicitly clear that they were talking about the first 8 floors of the building.

Question 5

Most candidates scored all three marks in part (i) with only occasional errors with the arrival time of the lift at the ground floor. Part (ii) differentiated well with only a minority of candidates obtaining the correct answer of 392 seconds.

Question 6

This part was nearly always correct although a significant number of candidates tried to apply their knowledge of probability distributions instead of using the more expected route of applying the given formula of $1-\left(\frac{f-1}{f}\right)^{n}$.

Question 7

The majority of candidates struggled with this final part and it was clear that many did not understand how to tackle this question. It was expected that the candidates would simply use Table 2 with a value of $n=15$ and read off the two values of f at 6 and 4 and obtain 5.6 and 3.9 respectively. They could then have concluded that these two values suggest that it is indeed a common occurrence for the cars to stop on every floor that they serve. Many candidates, however, gave an answer that was not mathematical or numerical in nature and so therefore scored no marks in this final part.

4755 Further Concepts for Advanced Mathematics (FP1)

General Comments

The impression was of many candidates who had a good appreciation of the demands of the specification, but who were often lacking the insight, precision and attention to detail that would have earned the highest marks. It was evident that much good advice from previous years had been assimilated. Many scripts showed candidates with a pleasing ability to express their arguments in an easily readable form. In many instances, however, algebraic notation was often carelessly written and there were many lapses in some of the simplest manipulations. Candidates should take care to answer the questions posed in the notation that the question has used. At this level exact answers are to be preferred where possible, but rounding is acceptable with stated accuracy. When decimal fractions were written down, and there were few places that required them, very few candidates bothered to state the accuracy of the result. Most candidates found that they could answer in the time available, but avoidable errors in the final parts of the last question may have been due to the need to rush to finish.

Comments on Individual Questions:

Question 1

Most candidates found that this was a straightforward starter, and many gained full marks. There was a fairly even split between those who demonstrated thorough understanding of the matrix work of the specification, and those who formed simultaneous equations from the given matrix set-up. Correct solutions earned full marks by either method. On the whole the latter method produced rather more numerical errors. A few candidates showed confusion between the determinant of the matrix **M** and its reciprocal, but were, none the less, able to formulate the correct inverse. Some lost marks through failing to identify clearly the value of x and the value of y. Overall, this was a well-answered question.

Question 2

This was another well-answered question. Some candidates failed to obtain the correct roots of the equation, either through incorrect use of the quadratic formula (usually sign errors) or from a failure to take the square root of the discriminant correctly. Final answers hopefully specified both modulus and argument of each of the roots, without leaving the examiner to deduce anything. If answers were left in modulus-argument form, which was not requested, the candidate has not made clear their understanding of the two terms. Arguments expressed to only two significant figures without stating this were not rewarded, and it was disappointing that so few candidates bothered to state accuracy when giving 3 or more significant figures. Writing down all the figures on the calculator display is not “appropriate accuracy”, either.

Question 3

Many good responses were seen here, the best showing efficiency in quick and easy methods in finding *q*. There were many choices in how to proceed. A surprising number of candidates, however, failed to find p and r from the given information. The equation $-\frac{p}{2}=6$ often produced an answer of $p=-3$, and similarly $r=5$ was obtained. Other candidates were in quadratic mode and used ‘product of the roots = -10’ to find *q*, not *r*. A valid method for finding the remaining unknown gained M1.

Question 4

This question was well answered by many good candidates. Others found it difficult.

(i) Errors seen in drawing the half line included incorrect starting points (usually the Origin or the point 1+*j*), full lines rather than half lines, and lines which failed to cut the real axis at an appropriate angle.

(ii) Most candidates were able to draw the circle with the correct centre and radius, touching the real axis at $z = 1$. Some circles failed to reach the real axis. Some were centred at the Origin and a few elsewhere.

(iii) Several areas were shown bounded by the line but inside the circle. Of candidates who had successfully answered parts (i) and (ii), the most frequent error was to shade down to the real axis.

In several cases it was extremely difficult to see any shading due to poor image quality after scanning. On the whole, hatching rather than pencil "fill" shows up better.

Question 5

(i) This part usually achieved full marks. Writing the sum $\sum_{r=1}^{n} 1 = 1$ was, predictably, the common error. Some wilful blindness in obtaining the given result was then evident.

(ii) Many candidates failed to spot the easy method of finding the sum in the denominator, by subtracting the sum of the first n terms from the sum of $2n$ terms. The commonly seen erroneous result was ¼. Some found an answer that was in terms of n and hoped this was a constant. Very few approached the problem by treating the sum as a simple arithmetic series. A few candidates tried out some numerical values of n and found the correct result for k. This verification received one mark provided more than one value had been tested.

Question 6

Yet again the number of students who fail to follow the recipe for Induction is surprising.

The candidates split into four camps.

1) Those who understood the idea of induction and did this perfectly. Good work. This question was well answered by the majority of candidates who had learned the required argument and expressed it well.

2) Others who also had the precise wording for the start and the finish, and wrote this down even though they did not have a middle section that supported their final assertions.

3) The third group, who got as far showing the n=k+1 term is in the desired form and then failing to be precise about the final wording.

4) Lastly those who did not seem to understand induction at all. There were not many of these.

The first four marks were usually obtained, with some latitude allowed for different ways of expressing the assumption of "true for $n = k$", (not the same thing as "assume $n = k$ is true"). Apart from some candidates who believed that they were dealing with a series, the central passage of algebra was successfully done. However the number of students who lost the final two explanation marks is extremely disappointing since this point is raised every year.

The wording that is unarguably acceptable has been set out in the mark schemes for many years.

"If it is true when n=k it is also true when n=k+1.

Since it is true for n=1, it is true for all positive integers n."

Question 7

The graph sketching problem is usually a welcome one in Section B. Many candidates are confident of what to do and are able to draw a careful sketch, which shows all the required features of the curve clearly.

(i) It would be good if all candidates gave conventional co-ordinates, in brackets, as requested, for the points where the graph crossed the axes, rather than embedding the necessary values in their working. If the values of both *x* and *y* were not seen, the mark was forfeit. The equations of the asymptotes were usually correct. The expression $y \to 3$ is not an equation. Occasionally either co-ordinates or asymptotes were forgotten.

(ii) In justifying the manner of the curve's approach to the horizontal asymptote, the calculations shown for large positive and negative values of *x* should each have a numerical result, the argument is not complete without one and the examiners do not reach for calculators. Most curves were shown correctly with full annotation of intercepts and asymptotes. The point $(-\frac{2}{3},0)$ was not always labelled. Asymptotic approaches should be clearly shown.

(iii) The solutions to the inequality were usually correct, especially for $x < 1$. The second pair was sometimes marred by wrongly including both ends, or wrongly excluding both.

Question 8

In (i) only occasional slips in arithmetic were seen. This part was well done by nearly all candidates.

(ii) Substitution and equating the imaginary part to zero was usually successful in finding *q*. It may have been pressure of time that led to some slips here, with q = 7 instead of q = -7. Again, errors in arithmetic sometimes led to an incorrect *r.*

(iii) Some candidates did not see a simple route through this part of the question, and having discovered the real root by trial, went to the trouble of factorising the cubic and finding the complex roots again. Full marks did depend on correct answers in part (ii). Some candidates are uncertain as to the difference between a root and a factor.

(iv) A correct solution was very rare. Most candidates quoted z = 1 as the root, some gave z = 0. Only a handful of the best candidates went about solving the equation by understanding, if not showing, the complete factorisation.

Question 9

(i) This was well done, apart from those candidates who stopped with position vectors and did not give coordinates.

(ii) A two-way stretch should not be described as an enlargement, so several candidates lost one mark. There should be an indication that 4 and 2 are scale factors or multipliers. '4 in the x-direction', for example, is inadequate and candidates should be aware that these details need precise descriptions.

(iii) Those candidates who multiplied the matrices the correct way round had no difficulty in obtaining the correct inverse matrix. There were errors in sequence seen when T^{-1} and M^{-1} were used. The determinant of the combined transformation was often put down as 52. Some candidates tried to solve equations for an unknown matrix mapping A''B''C'' to ABC which was cumbersome as a method, and prone to mistakes.

(iv) This part seemed to be found surprisingly hard, but it may be that time pressure was preventing careful thinking.

Some knew that the determinant is the scale factor, and used it on the area of the initial triangle, but often came to grief by failing to obtain the area correctly. Diagrams often revealed B and C wrongly plotted.

Others tried to work out the area of the triangle having worked out its co-ordinates. Some candidates plotted these co-ordinates incorrectly. Some worked out the area using sine rule and cosine rule from their sketch, although " ½ b x h" would have served perfectly well.

4756 Further Methods for Advanced Mathematics (FP2)

General Comments

Most candidates demonstrated a sound working knowledge of all the topics being examined, and appeared to have sufficient time to complete the paper. When marks were lost, this was very often due to a lack of care rather than a misunderstanding of the concepts. The average marks on all four questions were quite similar but, by a small margin, Q.3 (on matrices) was the best-answered question, and Q.4 (on hyperbolic functions) was the worst.

Comments on Individual Questions

Q.1(a)(i) Many candidates made hardly any progress here; for example, expressing $x = r\cos\theta$ and $y = r\sin\theta$ in terms of θ, followed by some fruitless manipulation, then giving up. Those who started by multiplying the given polar equation by r quickly obtained a suitable cartesian equation from which the centre and radius could be deduced. Very many omitted to mention why the circle passed through the origin; this shows how important it is for candidates to read through the questions very carefully, making sure that they have answered every part.

Q.1(a)(ii) The method for finding the area was well understood, and was very often carried out accurately. A frequent error was to expand $(2\cos\theta + 2\sin\theta)^2$ as $(4\cos^2\theta + 4\cos\theta\sin\theta + 4\sin^2\theta)$. Many candidates used double angle formulae to integrate $\cos^2\theta$ and $\sin^2\theta$, instead of using $\cos^2\theta + \sin^2\theta = 1$ first.

Q.1(b) Most candidates understood the process of finding a Maclaurin series and obtained the given result correctly. As the answer is given on the question paper, full working must be shown, and this included some indication that f(0) = 0. In the final part, most candidates used $\ln(1 + t) - \ln(1 - t)$, although many took $\ln(1 - t)$ to be $-\mathrm{f}(t)$ instead of $\mathrm{f}(-t)$, leading to the common wrong answer of $2t - t^2$.

Q.2(a)(i) This part was well-answered.

Q.2(a)(ii) This was also well-answered, with most candidates using the expected method of expanding $(\cos\theta + \mathrm{j}\sin\theta)^5$. An alternative approach, taken by many candidates, was to rearrange the result from part (i) and then express $\cos 3\theta$ in terms of $\cos\theta$ and $\cos^3\theta$.

Q.2(b)(i) Most candidates obtained the correct values of w in exponential form. Common errors included taking the argument of the real number $4\sqrt{2}$ to be $\frac{1}{2}\pi$ or π instead of 0, and not simplifying the fifth root of $4\sqrt{2}$ to $\sqrt{2}$. Indicating the five values on an Argand diagram was generally done well, although many diagrams did not include any indication of the scale.

Q.2(b)(ii) The pentagon was usually enlarged and rotated correctly to show the values of v. Many candidates made no attempt to find an equation. Those that did often left $32e^{\mathrm{j}\pi/2}$ in their final answer, when this should have been simplified to 32j.

Q.3(i) The expansion of $\det(\mathbf{M} - \lambda\mathbf{I})$ was done extremely well and most candidates obtained the characteristic equation, and the three eigenvalues, correctly.

Q.3(ii) Most candidates understood the concept of eigenvectors and knew how to find them. Some did as intended and verified that the two given eigenvectors worked, but very many found all three by solving equations.

Q.3(iii) This part was very well answered.

Q.3(iv) Most candidates understood the Cayley-Hamilton theorem and were able to obtain $\mathbf{M}^4$. Careless errors such as going from $\mathbf{M}^3 - 6\mathbf{M}^2 - 7\mathbf{M} = \mathbf{0}$ to $\mathbf{M}^4 - 6\mathbf{M}^3 - 7\mathbf{M} = \mathbf{0}$ or $\mathbf{M}^3 = 6\mathbf{M}^2 - 7\mathbf{M}$ were fairly common.

Q.4(i)-(ii) These parts were answered well. Throughout this question, some candidates lost several marks through carelessness such as writing sec where sech was intended, or tanh where artanh was intended.

Q.4(iii) Here candidates were required to use partial fractions to obtain the integral. Two of the four marks were given for including a constant of integration and then showing it to be zero. Very many candidates omitted this essential part of the argument.

Q.4(iv) Most candidates integrated correctly and showed sufficient working to justify the given result. Many did not go on to express the answer in logarithmic form, even though the relevant formula is given in part (iii).

Q.4(v) Most candidates understood how to apply integration by parts to this integral. Common errors in the final answer were failure to write artanh(x) in terms of logaritms, an incorrect sign for the $\frac{1}{2}\ln(1 - x^2)$ term, and omission of the arbitrary constant.

4757 Further Applications of Advanced Mathematics (FP3)

General Comments

Most candidates for this paper were well-prepared, and were able to produce substantial attempts at all three of their chosen questions. Q.1 (on vectors) and Q.2 (on multi-variable calculus) were the most popular questions, each chosen by about 80% of the candidates. By far the least popular question was Q.3 (on differential geometry), which was chosen by about one third of the candidates. The standard of presentation, and the accuracy of algebraic and numerical work, was generally good throughout the paper.

Comments on Individual Questions

Q.1(i) Many candidates appeared to be unsure of how to tackle this; for example, starting by finding the perpendicular distance from A to the line, followed by some unproductive work, before settling down to the correct method. This consisted of expressing the distance from A to a general point on the line in terms of λ, and hence forming an equation. When this was done, the equation was almost always solved correctly to find the points B and C. Some candidates produced the correct points B and C with no apparent reasoning (presumably by trial); this was acceptable provided that *both* the required conditions (lying on the given line, and distance 15 from A) were convincingly verified.

Q.1(ii) The usual method was to use a vector product to find a normal vector to the plane; this was almost always completed successfully. Those who started with a parametric equation for the plane then eliminated the parameters, or who started with three simultaneous equations, were much more likely to make careless errors.

Q.1(iii) A substantial number of candidates scored no marks in this part. The required normal vector is perpendicular to the line BC and to the normal found in part (ii). Candidates who realised this could form a suitable vector product, which was then usually evaluated accurately. It was acceptable to take the given answer and verify that it satisfied the required conditions; but a candidate would not be given any credit unless *all* the conditions (containing BC and being perpendicular to the plane ABC) were considered. An elegant method, used by a few candidates, was to spot that the required normal vector is AM, where M is the mid-point of BC.

Q.1(iv) The method for finding the shortest distance between skew lines was very well-understood, and most candidates answered this part confidently. Several candidates lost marks because they just stated that the length of the vector $(-85, 21, 1)$ was $\sqrt{(7667)}$ without showing how this was calculated. As always, when an answer is given on the question paper, full and convincing working must be shown.

Q.1(v) The method for finding the volume of a tetrahedron, using a scalar triple product, was well known, and the correct answer was very often obtained.

Q.2(i) The partial differentiation was usually done correctly, and the stationary points found successfully.

Q.2(ii)(*A*) This involved substituting into the equation of the surface and rearranging. Many candidates lost marks because they did not show convincingly how the required result followed from their working. Some candidates tried to use an approximate result for small changes using the partial derivatives, although an exact result was required here.

Q.2(ii)(*B*) This was clearly unfamiliar work, and most candidates scored no marks in this part. Many candidates thought that both second derivatives being positive (or the sections in $x = 8$ and in $y = 4$ both having a minimum) was sufficient to show that the surface had a minimum. To obtain marks, it was necessary to explain convincingly how the result in part (*A*) shows that $p > -4$ for all small values of h and k.

Q.2(ii)(*C*) In this part, most candidates found the required sections and correctly deduced that B was a saddle point.

Q.2(iii) This part was very well-answered.

Q.2(iv) Candidates who started with $\partial z/\partial x = \partial z/\partial y = -6$ were usually able to complete this successfully. Having obtained $y = 3$, $x = 5$, $z = 9$, a fair number of candidates gave the coordinates of R as (3, 5, 9) instead of (5, 3, 9). Common misunderstandings were $\partial z/\partial x = \partial z/\partial y = 6$ and $\partial z/\partial x = \partial z/\partial y = 6\lambda$.

Q.3(i) Most candidates were able to use the parametric version of the formula to find the radius of curvature. Some tried to use the version involving dy/dx and d^2y/dx^2, but d^2y/dx^2 was never found correctly. The centre of curvature was often omitted, or incorrect. Many worked out the normal vector at A by differentiation rather than by inspection from the diagram, and some went the wrong way.

Q.3(ii)-(iv) These parts were generally answered well.

Q.3(v) Most candidates approached this by finding the equation of the normal to the ellipse at a general point, then differentiating partially with respect to θ. Others found the centre of curvature at a general point by using the radius of curvature and the unit normal vector, but this was more complicated. It was then necessary to obtain x and y in their simplest forms so that θ could be eliminated to obtain the cartesian equation. This provided a considerable challenge, and few candidates were able to complete it.

Q.4(i) Most candidates dealt with the identity and inverses correctly. For closure, very many candidates thought that it was sufficient to consider the square of a general element.

Q.4(ii) Most candidates were able to demonstrate that the group was not commutative Some confused commutativity with associativity.

Q.4(iii) Those who considered $k^2 = k$ as the condition for closure very often scored full marks. Some candidates gave a fully correct proof based on $kc + b/k$ having to be an integer for all integers b and c.

Q.4(iv)-(v) These parts were answered correctly by almost every candidate.

Q.4(vi) Most candidates correctly decided that R was not isomorphic to P, although this assertion was not always fully justified. Those who wrote out the combination table for R could easily show that the patterns were different. Many candidates based their arguments on the orders of the elements; and here, if the table for R was not given, they were also required to explain why the common value of $a*a = b*b = c*c$ had to be e. The simplest argument, given by quite a few candidates, was 'In P, the squares of the three non-identity elements are not all equal, but in R, $a*a = b*b = c*c$.'

Q.5(i)-(ii)(*A*) These parts were almost always answered correctly.

Q.5(ii)(*B*) Most candidates appreciated that the factories visited on Day 2 and Day 7 were not independent, and so they needed to use the probabilities for Day 2 and the diagonal elements of $\mathbf{P}^5$ to calculate the required probability.

Q.5(iii) Most candidates obtained the correct equilibrium probabilities and explained that these were the long run probabilities of visiting each factory. Some solved simultaneous equations resulting from the equilibrium condition, but the most common method was to consider $\mathbf{P}^n$ for large values of n. Having obtained the limiting matrix $\mathbf{P}^n$, some candidates did not write out the resulting probabilities for the factories A, B, C.

Q.5(iv) This part was very well answered.

Q.5(v) Many candidates used the formula $p / (1 – p)$ or $1 / (1 – p)$ to find the expected run length, usually with the correct value $p = 0.8$. Then 1 might be added or subtracted to give their answer. The correct answer (4) very often resulted, but 5 was a very common error.

Q.5(vi) The transition matrix **R** was usually given correctly, and many candidates considered the appropriate element in the powers $\mathbf{R}^n$. Answers of Day 24 or Day 26 (instead of Day 25) were fairly common.

Q.5(vii) Most candidates understood the concept of an absorbing state.

4758 Differential Equations (Written Examination)

General Comments

The standard of the responses on this paper were of a pleasingly high standard, and many candidates scored full marks on some or all of the questions. The methods required to solve the second order differential equations in Questions 1 and 4 were known by almost all candidates and these two questions were attempted by the majority of the candidates. Questions 2 and 3 were chosen by candidates in roughly equal measure. Each of these two questions had parts that some candidates found quite challenging.

Comments on Individual Questions

Question 1

Second order linear differential equations

(i) All candidates were familiar with the method of solution required in this part. Any marks lost were because of arithmetical errors in solving either the equations to find the particular integral or the quadratic equation to find the roots of the auxiliary equation.

(ii) The maximum displacement of the particle was most easily found by differentiating the solution, $x = \frac{1}{12}e^{-4t}\sin 3t$, found in part (i) and equating this derivative to zero. This resulted in the simple trigonometric equation, $\tan 3t = 0.75$, with solution $t = 0.2145$, giving x =0.0212. A significant minority of candidates simply ignored the exponential part of the solution and stated that the maximum value of x occurs when $\sin 3t = 1$.

(iii) For large values of t, the solution for x indicates oscillatory motion with decreasing amplitude. The majority of candidates stated only that x tended to zero.

(iv) As in part (i) all candidates were confident in applying the correct method of solution and any loss of marks was due to arithmetical or algebraic slips.

(v) For large values of t, this new solution for x indicates oscillatory motion with approximately constant amplitude $\frac{1}{8}$. Many candidates described this situation fully. Some candidates stated the form of the solution for large values of t but did not go on to comment on what type of motion this represented.

Question 2

First order differential equations

(i) Almost all candidates recognised that the given differential equation required the application of the integrating factor method and most began correctly by dividing through by x, the coefficient of $\frac{dy}{dx}$. Most candidates found the correct integrating factor. Some candidates made a sign error and obtained x^n instead of x^{-n}. Often it was not clear whether this was a slip or a misunderstanding of the fact that the calculation of the integrating factor must include the sign in the coefficient of x in the differential equation. A variety of errors appeared in the ensuing integration, with the negative algebraic powers of x causing more problems than might have been expected.

(ii) Most candidates applied the initial condition to their solution in part (i) and were awarded a method mark. For the sketch, follow through marks were available for any solution of the correct form. One mark was awarded for a curve that passed through the given point (2,0) with a positive gradient at that point. The second mark was awarded for a curve that had the correct asymptotic behaviour for small and large positive values of x. Those candidates who had obtained the correct solution in part (i) usually produced good sketches and scored full marks in this part.

(iii) Candidates were asked to consider the case $n = 1$. Some candidates applied this value of n to the first part of their work in part (i) while others began again with the new differential equation. It was interesting to note that finding the integrating factor from scratch, for this particular case, was usually done correctly, without the sign errors of part (i).

(iv) Most candidates used the initial condition and then differentiated and equated their derivative to zero. Those who worked accurately usually found the correct x value of the single stationary point.

(v) Almost all candidates rearranged the given differential equation into the form required to apply Euler's method and many scored full marks. Other candidates gave a list of numbers, none of which related to the correct ones, and it was not possible to award any marks. Sight of either 0.921 or 0.192(1) or equivalent was required as evidence that the method was being applied correctly.

Question 3

First order differential equations

Each of the first three parts of this question required a statement of Newton's second law of motion with the acceleration written in the appropriate form for the request, for example in part (i) involving v and x. Candidates who appreciated this usually made good progress and scored the majority of the marks.

(i) This part required a straightforward application of the method of separation of variables resulting in a logarithmic expression involving v. The majority of candidates who started from the correct form of the acceleration, $v\frac{\mathrm{d}v}{\mathrm{d}x}$, almost always worked accurately and found the given expression for v^2 in terms of x. The minority of candidates who worked with $\frac{\mathrm{d}v}{\mathrm{d}t}$ did not gain any credit in this part. However, a number of candidates did realise when they moved on to part (ii) that they had already done the work in part (i) and indicated this. An indication such as this earned the relevant marks in part (ii), but could not be credited without the candidate making it clear to the examiner that the link had been made.

(ii) This part attracted either full marks or no marks, depending on whether or not a candidate realised that the way forward was to find v in terms of t and then use the numerical value for v from part (i). A significant number of candidates made valiant attempts to integrate the expression for v in terms of x obtained by taking the square root of the given expression in part (i). Without exception they were unsuccessful.

(iii) Candidates were back on firmer ground in this part and most produced accurate solutions. The differential equation resulting from Newton's law can be solved by using the integrating factor; by separating the variable; or by finding the complementary function and particular integral. Most candidates opted for separating the variables, but it is worth noting that the last of the three approaches mentioned was the most straightforward. Candidates are confident in applying this method to a second order linear differential equation, but do not seem to consider it as an option when dealing with a first order linear differential equation.

(iv) This was a simple numerical substitution. Follow through was not given, so the one mark available was a reward for accurate working in parts **(i)** and **(iii).**

Question 4

Simultaneous second order linear differential equations

(i) There were many excellent responses to this part and the majority of candidates scored full marks. The most common error was a numerical slip when finding the coefficients in the particular integral.

(ii) Almost all candidates gained the two method marks and the majority also gained the accuracy mark.

(iii) All candidates made a good attempt at this part and most produced accurate solutions.

(iv) Most candidates realised that they needed to equate their expression for *x* to zero. The resulting equation involved three different exponential terms and the key to making progress was to multiply through by $e^{0.5t}$, yielding a quadratic equation in e^{t}. A pleasingly high number of candidates took this step and went on to score full marks.

(v) Many candidates made the correct comment that the number of species *X* becomes negative for times greater than *T*, indicating that they understood the implications of the predictions of the model situation that was being modelled.

4761 Mechanics 1

General Comments:

This paper was answered well by a large majority of the candidates. They showed good understanding of the principles underpinning mechanics at this level and of the particular techniques needed to answer the questions. Almost all candidates were able to answer at least some of the questions and so show what they could do.

The two areas that caused the greatest difficulty, and so loss of marks, were connected particles (question 2) and two-stage motion (question 7).

There was no evidence of the paper being found too long for the available time. Many candidates provided attempts at all the parts of all the questions.

Comments on Individual Questions

Section A

1. (Forces in equilibrium)

This question was answered correctly by almost all candidates. A small number made sign errors, particularly when finding *Q*. There were also those who did not give *Q* to 3 significant figures, as requested in the question.

2. (Connected particles)

This was the least well-answered question on the paper. Paradoxically it was probably the most routine of all the questions.

In part (i) candidates were asked to draw separate diagrams showing the forces on the three objects. There were two strings and the tensions in them were different. However, many candidates treated them as the same and just marked them as *T*. This was obviously a serious mistake which undermined the whole question and so caused a large loss of marks both in part (i) and, if continued, in part (ii).

In part (ii) they went on to find the acceleration of the system and the tensions in the two strings. Those who had drawn correct diagrams in part (i) usually got this completely correct but those who had not done so, rarely made much progress on this part.

3. (Vectors)

This question tested vectors in the context of two hikers. Most candidates answered it well and many obtained full marks. A few, but not many, did not know how to relate the information given in the equations in the question to the subsequent requests.

In part (i) they were asked to prove the two hikers meet and this involved showing their position vectors are the same at some time ($t = 2$). Many lost a mark by not showing that this was true for both components when the position vectors were equated.

In part (ii) they were asked to compare the speeds of the two hikers and most got this right. A few compared their velocities. Others did not know how to obtain the velocities from the given expressions in terms of *t* for the position vectors.

4. (Uniform acceleration)

This question, about the motion of a car on a road, was very well answered and nearly all candidates got the first 7 marks for selecting and using appropriate constant acceleration formulae.

The final part, for 1 mark, asked them to explain why the time to the mid-point of the distance is more than half the time for the whole journey (the car was accelerating throughout). This produced a number of excellent answers but many were unconvincing. A good answer made the point that the distance is the same in both parts but, because it is accelerating, the car is travelling slower in the first part than in the second part, and so takes more time.

5. (Projectile)

This question started with finding the equation of the trajectory of a projectile and then went on to apply it to the flight of a golf ball. It was very well answered. It was particularly pleasing to see that almost all candidates were able to handle the algebra in the first two parts.

In the final part candidates had to investigate whether the ball passed above, below or hit a hovering bird. This was easily done using the equation of the trajectory but some candidates found other interesting and valid methods.

Section B

6. (Motion on a slope)

This question was answered very well and many candidates got it completely right.

Almost all candidates were successful on part (i) involving the use of Newton's 2nd Law.

Part (ii) was about pushing a car up a slope. This was well-answered with most candidates resolving the weight correctly to find its component down the slope. Very few made the mistake of interchanging sin and cos.

In part (iii) the car was still being pushed up the slope but an extra force was now involved. This meant that the equation of motion had five terms and some candidates lost marks by omitting one (or more) of them.

In part (iv) the car travelled down a slope and many candidates were able to select the right information and methods to deal with this new situation. Some lost marks by forgetting one of the terms, for example the resistance.

Overall the response to this question was very pleasing.

7. (Two-stage motion)

This question was about a helicopter dropping a box of emergency supplies. Initially the box accelerated but then it reached terminal speed so there were two stages to the motion. Some candidates found this quite difficult to deal with.

In part (i) they were asked to find the velocity in each stage of the motion. This required the use of calculus and was quite well-answered. A common mistake was to omit the explanation that the terminal velocity is constant because the acceleration is known to be zero.

Part (ii) involved drawing a velocity-time graph for the two stages of the motion. This was well-answered but some candidates gave a straight line rather than a curve for the first stage.

Part (iii) involved going from the velocity of the box to its height and so involved further use of calculus. That part was well-done but many candidates failed to deal adequately with the sign change involved in going from the distance fallen from the helicopter to the height above the ground.

In part (iv) candidates were asked for the time taken for the box to fall. Only a few candidates got this right. Almost all forgot that there were two stages to the motion. Many set the cubic expression for height equal to zero and then tried to solve the resulting cubic equation. The correct approach was nothing like as difficult as that.

In part (v) two alternative methods of trying to limit the damage to the box on landing were considered. The first, in part (*A*), involved reducing the height from which the box was dropped; however, it would still have reached terminal velocity so this would not have helped. This was not answered very well with many candidates missing the point. The second, in part (*B*), involved fitting a parachute and this was very well answered, with many candidates obtaining full marks on it.

Overall this question was not answered badly. It was not difficult but a high mark on it did require clear thinking.

4762 Mechanics 2

General Comments

The standard of the solutions presented by candidates was generally pleasing. There was the usual wide spread of marks, but most candidates were able to make a reasonable attempt at most parts of the paper. There was some evidence that candidates felt rushed towards the end of the paper.

As always, candidates should draw clear and labelled diagrams and these are always appropriate when dealing with forces or velocities. A lot of potentially very good work was marred by sign errors that, perhaps, could have been avoided by having a clear diagram.

The responses to Question 3 were particularly pleasing, with candidates showing themselves very capable of applying their knowledge of algebra dealing with an unusual example involving centres of mass.

The work-energy scenario for Question 2 did not seem familiar to some candidates and many seemed to struggle with the presence of two connected objects.

Comments on Individual Questions

Question 1

Forces and Equilibrium

Candidates seemed confident in their attempts at this question, and many earned the majority of the marks. Some solutions were much longer and more complicated than they need have been. Candidates should choose carefully the points about which they take moments and the directions in which they resolve.

(i) Most candidates realised that taking moments about the peg or the point of contact of the rod with the cylinder resulted in an equation involving only one of the unknown forces. The second of the forces was then found by a second moments equation or, more commonly, by resolving in the vertical direction.

(ii) Again, the point about which candidates took moments was key to the success of their solution. Those who did not opt for the point of contact of the rod with the cylinder usually missed out at least one relevant force. Some candidates did not use the fact that for the greatest value of W the reaction at the peg is zero.

(iii) In this part, the key to a concise solution was to make appropriate choices for the point(s) about which to take moments and the directions in which to resolve. Taking moments about the point of contact of the rod with the cylinder, leaves S as the only unknown force. Resolving parallel and perpendicular to the rod gives equations involving only one of F and R, together with known forces. Those candidates who adopted this approach almost always scored full marks.

Many candidates had a clear idea as to what needed to be done but made errors, notably with the inclusion, or not, of the correct trigonometric functions in moments equations and resolutions.

(iv) The vast majority of candidates considered the particular case of limiting friction rather than the general case. They found an equality instead of an inequality for μ in terms of $\tan\theta$.

Question 2

Work, Energy and Power

There were two different approaches to this question, one using energy methods and the other using Newton's second law of motion and *suvat* equations. Candidates opted for these approaches in roughly equal measure, with the second often proving more successful. For a significant number of candidates, the scenario involving two particles connected by a string seemed to cause confusion.

(i) Candidates were required to find the change in the gravitational potential energy of each of the particles P and Q, as each moved through a distance *h* m. Most candidates did this successfully, the most common error being omission of the $\sin 30^\circ$ needed in calculating the vertical distance moved by Q.

(ii) *(A)* and *(B)* A very common error in this part was to use different masses in different parts of either the work-energy equation or Newton's second law equation. For example, in the work-energy equation, many candidates used both masses in the gravitational potential energy term, but only one of the masses, usually that of P, in the kinetic energy term.

(iii) The majority of candidates calculated correctly the magnitude of the frictional force, and gained two marks. Confusion arose again over which mass should be used in the gravitational potential energy and kinetic energy terms required for one method or in the force terms in Newton's equation required in the other.

(iv) An attempt at a comparison of the forces up and down the plane was required here. Those candidates who stated these forces and reached the conclusion that the system stayed at rest usually gained both available marks. However, many candidates stated that the system stayed at rest, with no reference to the situation under consideration, and often in a verbose essay-type response. Without reference to the numerical values of the forces involved, no marks were awarded.

(v) Most candidates multiplied their frictional force from part (iii) by the given speed and gained both marks.

Question 3

Centre of Mass

Candidates were on familiar territory with the content of this question and there were many very good, well-presented solutions.

(i) In this part, candidates were asked to find the position of the centre of mass of a lamina made from the removal of a square of side 1 unit from the corner of a larger square of side *a* units. Many candidates tackled this problem by considering the removal of the smaller square. This led to a simple formula, which could be simplified further by use of a given identity. Some candidates preferred to look at the problem by considering two or even three rectangles of different sizes. This led to more tricky algebra and often resulted in errors.

(ii) Candidates were asked to show that the centre of mass of the lamina was on its perimeter for $a = \frac{1}{2}\left(1+\sqrt{5}\right)$. Only a minority of candidates transformed this into the fact that $\bar{x} = 1$ and solved the resulting quadratic equation $a^2 - a - 1 = 0$. Most candidates substituted $a = \frac{1}{2}\left(1+\sqrt{5}\right)$ into the formula for $\bar{x}$ and with a small amount of surd algebra were able to show that $\bar{x} = \bar{y} = 1$, a point on the perimeter of the lamina.

(iii) Candidates were asked to consider a lamina formed by adding a mass to the lamina used in part (i), and to find the angle made by line AB to the vertical when it was suspended from A. Most candidates obtained the first five marks for finding the centre of mass (G) of the new shape and many went on to find the angle between AB and the vertical. The most common method was to find the angle that AG made with AO and then subtract this from 45^0. There were many other ingenious solutions, with techniques including

- the use of the cosine rule in the triangle AGB
- the dot product of vectors $\overrightarrow{AB}$ and $\overrightarrow{AG}$
- the intersection of lines the $y = 4 - x$ and $y = x - 1$ at a point M leading to the formation of triangle AGM from which the angle could be found.

Question 4

Momentum and Impulse

Candidates showed confidence in their working for this question and many applied the relevant principles and equations to good effect. It was disappointing that some marks could not be awarded for otherwise good work, because of a lack of clarity about directions. It seems very likely that copying the diagram given in part **(a)** and adding the magnitude and direction of the velocity of each disc would have led to more clarity and accuracy.

(a) (i) The majority of candidates were able to interpret and use the given information that P lost $\frac{5}{9}$ of its kinetic energy in the form that the final kinetic energy of P was $\frac{4}{9}$ of its initial value. The speed of P was usually found correctly, but it was rare to see a convincing argument as to why the *velocity* should be - 4 and not 4.

(ii) Most candidates knew the appropriate formulae to calculate the impulse on P and the average force on the discs, but sign errors were common. It was almost invariably the case that a candidate who had drawn a clear diagram, with directions shown, used the correct signs in the ensuing calculations.

(iii) The equations resulting from applications of the Principle of conservation of linear momentum and of Newton's law of restitution were usually correct and most candidates solved them correctly to find the speed of Q and the coefficient of restitution. As in part (i), there was a lack of clarity in identifying the resulting direction of motion.

(b) (i) There are four stages in calculating the height reached by the particle after it bounces from the plane: finding the vertical component of the initial velocity, finding the vertical speed with which the particle hits the plane, applying Newton's law of restitution at the collision and finally, using a *suvat* equation to find the height of the bounce. The majority of candidates worked methodically and accurately through these stages.

(ii) Candidates were required to find the horizontal distance travelled by the projectile from its projection to reaching its maximum height after bouncing off the surface. The calculation of the time for each part of the motion was often not completed by candidates. It was not clear whether this was due to a misunderstanding of the problem, or that the end of the examination prevented any further work.

4763 Mechanics 3

General Comments

Most candidates demonstrated a sound understanding of the topics being examined, and were able to complete the paper in the time allowed. The relevant techniques were generally applied confidently and accurately, and the work was usually presented well. The best answered questions were those on dimensional analysis and centres of mass; the questions on circular motion and elasticity were not answered quite so well.

Comments on Individual Questions

Q.1(i)-(iv) These questions on dimensional analysis were answered correctly by most candidates.

Q.1(v) Most candidates correctly gave the value of λ in SI units, and many then converted it to the new units using the dimensions found in part (ii). Another approach, quite often used, was to convert P and U into the new units before calculating $\lambda = P / U^3$, and this tended to be less successful. Conversion factors were frequently inverted.

Q.1(vi) The most common method was to use the equation from part (iv) to find the value of k, find the value of λ for Car D (this step was often omitted), and then use the equation from part (iv) again to find the new time. Some candidates used the slightly more efficient method of considering ratios, which avoids the need to find k (although it still requires finding the new value of λ).

Q.2(a) Most candidates gave the radial equations of motion involving the tensions at the highest point and at the general point. Some candidates assumed that the speeds in the two positions were equal. To make further progress it was necessary to relate the two speeds using the conservation of energy (kinetic and gravitational). The algebra required to eliminate the two speeds and obtain the given result was usually done correctly, but it was very often more complicated than it needed to be.

Q.2(b)(i) To find the tensions it was necessary to resolve vertically for any two of Q, R, Q and R together. All three possible combinations were seen, the most common being R followed by Q. Many candidates were not sufficiently careful when selecting the appropriate forces for each equation.

Q.2(b)(ii) Most candidates correctly considered the radial equation of motion for R. The most common error was to use an incorrect value for the radius.

Q.2(b)(iii) Here it was necessary to form the radial equation of motion for Q, involving the tensions in all three strings. Candidates who were sufficiently careful often completed this successfully.

Q.3(i) The equilibrium position C was usually found correctly.

Q.3(ii) To obtain full marks in this part, candidates were required to form an equation of motion in which the tension in each string appeared explicitly in terms of x. A large number of candidates failed to do this.

Q.3(iii)-(v) Most candidates were able to apply the standard simple harmonic motion formulae successfully in these parts.

Q.3(vi) To earn any marks in this part it was essential to realise that the simple harmonic motion performed from B to D changes (to a different centre and period) when the right-hand string goes slack. The best way to find E was to use conservation of energy (kinetic and elastic). Many candidates used the simplest method (considering B and E); another popular choice was C and E, and another was D and E (even though this involved finding the speed at D first).

Q.4(a) The technique for finding the centre of mass of a lamina was very well-understood and usually applied accurately. Errors sometimes occurred in the *y*-coordinate, such as losing the factor ½ at some stage of the working, or mishandling the powers of *a*.

Q.4(b)(i) The centre of mass of the solid of revolution was usually found correctly.

Q.4(b)(ii) Most candidates treated this as a composite body problem, using their answer from part (i); the only common error here was the loss of a factor π from some of the terms. Some candidates did try to tackle the new solid of revolution directly, but very few of these achieved any marks.

4764 Mechanics 4

The work on this unit was generally of a very high standard. Many of the candidates were very competent and demonstrated a sound understanding of the principles of mechanics covered in this module. However, a small number of candidates struggled with the majority of the paper and were not able to apply principles appropriate to the situations. The majority of candidates seemed to be particularly confident when solving differential equations and manipulating complicated expressions and most demonstrated a solid knowledge of the techniques and concepts required. Candidates appeared to have had sufficient time to complete the paper. The standards of presentation and communication were high, though some candidates failed to include necessary detail when establishing given answers.

Comments on Individual Questions:

Question No. 1 – Variable mass

In part (i) the majority of candidates correctly derived the differential equation for the motion of the rocket though some failed to account properly for the signs of their δm term. The technique of separation of variables and integrating was well understood and executed well by nearly all candidates. Most went on to use the correct initial conditions to determine the constant of integration and the majority then went on to derive the given result correctly.

Part (ii) was answered extremely well and nearly all realised that it took 24 seconds to eject all the fuel from the rocket. Nearly all candidates correctly used this result, and the given answer from part (i), to obtain the correct value for the maximum possible initial mass of the rocket.

Question No. 2 – Equilibrium

Part (i) was done extremely well by the vast majority of candidates and nearly all handled the necessary calculus and trigonometry accurately to derive both V and the given result for $\frac{\mathrm{d}V}{\mathrm{d}\theta}$.

In part (ii) nearly all candidates stated that when the first derivative of V was zero then either $\cos\theta = 0$ or $\sin\theta = \frac{1}{4}$. For the case when $\cos\theta = 0$ some did not realise that $\theta = -\frac{1}{2}\pi$ was a position of equilibrium. Furthermore, for the case when $\sin\theta = \frac{1}{4}$, the majority of candidates did not consider (and subsequently reject) $\theta = \pi - \arcsin\left(\frac{1}{4}\right)$. Most candidates correctly went on to find the second derivative of V and they knew that they had to find the sign of the second derivative for their values of θ. In general, the work for $\theta = \pm\frac{1}{2}\pi$ was very good, but many struggled to make any progress with $\theta = \arcsin\left(\frac{1}{4}\right)$, often because they did not rewrite their expression for the second derivative of V in terms of $\sin\theta$.

Question No. 3 – Variable force

Part (i) was done extremely well and candidates were split in adopting one of two methods for finding the impulse and velocity of the particle over the first 3 seconds:

- The majority calculated the impulse of the force by considering the definite integral $\int_0^3 20te^{-t}\,dt$ and then used the fact that the impulse is equal to the change in momentum to calculate the velocity of the particle.
- The minority formed, and then solved, the differential equation $4\frac{dv}{dt} = 20te^{-t}$ for the velocity of the particle and then went on to find the corresponding impulse.

Whichever method was adopted, the subsequent integration by parts was done extremely well and in most cases the correct values for the impulse and velocity were found.

Part (ii) was also answered very well and most began by considering $20te^{-t} - \frac{1}{2}t = 0$ with nearly all correctly deriving the given result that $t = \ln 40$. However, a number of candidates, when solving this equation, did not consider (and subsequently reject) the second solution that $t = 0$. In finding the maximum velocity nearly all candidates wrote down and solved the correct differential equation using the correct initial conditions. The most common error in this part was to use incorrect initial conditions; a number of candidates, while correctly using their v from part (i), had $t = 0$ rather than the correct value $t = 3$. Finally, very few candidates justified that the velocity of the particle was indeed a maximum at the given time of $t = \ln 40$.

Part (iii) discriminated well as the majority of candidates gave an argument that in essence said that as $T \to \infty$, $e^{-T} \to 0$ which, though mathematically correct, was not strictly valid in the context of this question. For the first mark examiners required an argument that for values of T close to 11 the expression $80e^{-T}(1+T)$ was small. Many candidates, however, did score the second mark for stating that as e^{-T} becomes small it could easily be deduced that $T \approx 11$.

Part (iv) was answered very well with the majority of candidates correctly using a numerical method to find T correct to 4 decimal places although a number showed no method (and simply stated the answer) or gave an answer which was not to the required number of decimal places.

Question No. 4 - Rotation

Part (i) was either done extremely well or little progress was made as a number of candidates did not realise that the parallel axis theorem was required to find the moment of inertia of the cylinder about the required end face. While the majority set out their working in a clear and methodical manner, a number of candidates, when setting up the problem by considering an elemental disc, omitted δx (or equivalent) from their expressions for the mass and corresponding moment of inertia. Those candidates who had the correct integral expression for the moment of inertia nearly always went on to derive the given result correctly.

Part (ii) was done extremely well and nearly all candidates correctly derived the given result for the centre of mass of the cylinder.

While most candidates in part (iii) correctly applied the parallel axis theorem to derive the stated moment of inertia of the cylinder (about the other end face) a number of candidates used integration (with variable success) and some did not show sufficient working to convince examiners that the given result had been derived correctly.

The responses to part (iv) were mixed; many candidates either made no response or were only successful in calculating the moment of momentum of the small object about the axis of rotation before the collision. While nearly all candidates (who attempted this part) gave the correct moment of inertia of the cylinder about the axis as 5.11, the moment of inertia of the object, due to the geometry of the problem, caused problems. The vast majority of candidates believed this to be 0.882 (incorrectly coming from $0.2(2.1)^2$) rather than the correct 0.98 (coming from $0.2\left(7/\sqrt{10}\right)^2$).

While most candidates appreciated the need to apply the conservation of angular momentum to find the initial angular speed of the combined object, a number of candidates incorrectly attempted to use an approach based on the conservation of mechanical energy.

4766 Statistics 1

General Comments

The majority of candidates coped very well with this paper and a large number scored at least 60 marks out of 72. There was no evidence of candidates being unable to complete the paper in the allocated time. Most candidates had adequate space in the answer booklet without having to use additional sheets.

Candidates performed fairly well on the first conditional probability question (question 2(ii)) but not very well on the second one (question 8(iii)). In question 5(iii), although candidates usually found the mean, median and mode correctly, many gave a poor explanation of whether or not the mode was useful. Many candidates found question 6(i) very difficult, often providing explanations that were not convincing. Question 7 on the binomial distribution and hypothesis testing was fairly well answered, with many candidates defining the hypotheses correctly, defining *p*, carrying out the hypothesis test correctly and also giving their final answer in context with an element of doubt. Question 8(v) was sufficiently challenging to differentiate between the best candidates.

As last year, most candidates supported their numerical answers with appropriate working, but when written explanations were required, the poor handwriting and in some cases the poor use of English of some candidates made it difficult to determine what they were trying to say.

Too many candidates are still losing marks due to over specification of some of their answers. Over a third of candidates lost a mark in question 1 and/or in question 6 part (ii) due to this. For example in Q1(i) candidates often gave an answer of 419.13, some adding ‘to 2dp’, which they thought was appropriate accuracy. Of course it is the number of significant figures rather than the number of decimal places that is important, and giving a standard deviation to 5 significant figures is not sensible and so attracted a penalty.

Comments on Individual Questions

Q1(i) Almost all candidates found the mean and most also found the standard deviation correctly, although this answer was often over specified to 419.13. It seems that candidates incorrectly think that the number of decimal places is the crucial thing rather than the number of significant figures. A few candidates made errors in calculating S_{xx} or calculated the variance or the root mean square deviation.

Q1(ii) This question was very well-answered with about two thirds of candidates scoring full marks. Full follow-through was allowed from answers to part (i). Few candidates lost marks for over-specification here as those who did had already lost a mark for this in part (i). The most common error was to add 14.5 to the standard deviation as well as the mean. A few candidates multiplied their answers by 40.

Q2(i)A This was answered very well, although a number of candidates gave the number that watched cycling and not football rather than the probability. A few had the wrong divisor, usually 186 or 100.

Q2(i)B Again this was very well-answered with only a small minority of candidates making errors. The most common errors were to include those people who watched all three sports or to miss out one of the six who watched 1 or 2 sports..

Q2(ii) Approximately two thirds of candidates answered this correctly. Of the rest, some were able to get a method mark for the correct denominator but then failed to get the correct numerator, often thinking that it was 12 rather than 15. Some candidates either did not recognize this as a conditional probability question, or did not know about conditional probability.

Q3(i) This was answered very well. However a few ignored the question and assumed 54 or 50 cards in a pack, or that the card had not been replaced. Another common wrong method was to find 1 - P(both aces) = $1 – (4/52)^2 = 168/169$.

Q3(ii) Surprisingly, only two thirds of candidates scored this easy mark. Most realised that they had to multiply their answer to part (i) by 10 but some then rounded their answer to a whole number, thus losing the mark. A smaller number incorrectly raised their answer to part (i) to the power of 10.

Q4(i) This was very well-answered.

Q4(ii) This was again usually answered well although a fairly common error was to add the two combinations rather than to multiply them.

Q4(iii) This was another well-answered question with even those who had added in part (ii) still usually scoring both marks on follow through. Candidates who tried to use a probability method (instead of simply dividing their answer to part (i) by their answer to part (ii)) were rarely successful, and even if they did have the correct product of 15 probabilities, they rarely multiplied this by any, let alone the correct combination.

Q5(i) Most candidates scored all three marks, although some did not accurately align the leaves or did not provide a suitable key and thus scored only 2 marks. Very few candidates scored less than 2 out of 3.

Q5(ii) This was very well-answered with only a few thinking that the skew was positive.

Q5(iii) The mean, median and mode were usually given correctly although one or two candidates lost a mark due to over-specification of the mean or rounding of the median. However the final mark for the comment was awarded to only under a quarter of candidates. Many candidates gave general descriptions of the usefulness of the mode rather than commenting on this particular case. Too many candidates stated incorrectly that the mode was useful. Those who correctly stated that it was not useful, often followed this with an incorrect reason such as being unaffected by outliers; data being negatively skewed; or not being close to the mean and/or median.

Q6(i) A variety of techniques was used to answer this question, including some novel approaches that at times were hard to follow. The most common approach was to sum the required combinations of 1, 2 and 3 sixes in the set rather than the neater solution of subtracting from 1 the combinations that were not required (no sixes). Unsurprisingly many candidates subtracted the other given probabilities from 1, gaining no marks.

Q6(ii) Candidates who worked in fractions almost always gained full credit, whether or not they converted to decimals at the end. Many candidates who worked in decimals lost a mark for over-specification. Some candidates also lost marks by not showing sufficient working despite getting answers fairly close to the correct ones. However, over three-quarters of candidates gained at least 4 marks out of 5.

Q7(i)A This was generally very well-answered.

Q7(i)B Although around two-thirds of candidates answered this correctly, some candidates included P(X=18) in their method and thus were only able to gain 1 mark out of 3.

Q7(i)C The majority of the candidates found this part straightforward, but a minority lost the mark when they rounded their final answer to 15 or 16.

Q7(ii) In recent years, candidates have been doing better on hypothesis test questions than in the past, and this was again the case this year. Many fully correct responses were seen. Most candidates scored the first three marks for the hypotheses, with most now knowing that they need to define p. The vast majority of successful candidates used the probability method, finding P($X \geq 19$) and then comparing this to 1%. It was pleasing to see that most candidates gave their final answer in context and with an element of doubt stating something to the effect of 'there is not enough evidence to suggest that…'. Those who tried to use the critical region method were less successful on the whole. Again some tried to use point probabilities, being able to gain only the first three marks for the hypotheses. A few candidates tried to use tables and there full marks available for correct interpolation from tables.

Q7(iii) Candidates who gained more or less full marks in part (ii) tended to gain full marks in this part. In this part no marks were available if point probabilities were used.

Q8(i) Most candidates calculated the inter-quartile range and used it correctly to find the limits for outliers. However a few used the median instead of the quartiles to add to and subtract from 1.5 × inter-quartile range. Many candidates neglected to comment on outliers at each end separately (only commenting if there were outliers overall).

Q8(ii) This question was answered well (even by candidates who had struggled with earlier questions). Many answers were left as fractions (which were exact) with very few marks lost for over-specification. However many candidates squashed their work up into the first part of the answer space, not realising that there was more space on the next page. A few candidates forgot to take into consideration 'non replacement' and starting with $(7/20)^3$, gained only 1 mark, although plenty of follow through marks were available in parts (iii) and (iv).

Q8(iii) Although over half of candidates gained at least 2 marks out of 3 here, a number of candidates did not use the straightforward $P(A|B) = P(A)/P(B)$ here, and instead mistakenly calculated $P(A \cap B) = P(A) \times P(B)$, and then cancelled out a term on the top and bottom of the fraction. This illustrates the lack of deep understanding here of independence and conditionality. A disappointing number of candidates were quite happy to give an answer greater than 1 for $P(B|A)$.

Q8(iv) This was well-answered although a common incorrect method was $2 \times P(A)$.

Q8(v) Only approximately a quarter of candidates produced a completely correct answer, although many went through the correct answer on the way to a wrong one. Most of the correct answers used the 6/20 × 5/19 method, with a large minority then compromising this with another term multiplied or added.

4767 Statistics 2

General Comments

The overall performance of candidates taking this paper was very good. It was again pleasing to see candidates taking care over the wording used when carrying out hypothesis tests, with the majority providing non-assertive conclusions referring to the alternative hypothesis. Most candidates demonstrated good understanding of the processes required. In general, statistical calculations were completed with success, though a minority of candidates seemed unsure where inequalities were involved. A minority of candidates used spurious continuity corrections when calculating Normal probabilities. Once again, fewer over-specified answers were seen than in previous years. There appeared to be more candidates making use of graphical display calculators this year, often with good success; however, where incorrect answers were provided and no method described, examiners could give no credit. Candidates seemed to have sufficient time to complete the paper and very few failed to complete all 4 questions.

Comments on Individual Questions

Question 1

(i) The scatter diagram allowed candidates to make a successful start to the paper, the only common errors being either omitting scales or labels.

(ii) The many successful attempts at this usually found the means, $\bar{t}$ and $\bar{y}$, first and then calculated the other required totals: $\sum t^2$, $\sum y^2$and $\sum yt$ before finding the regression line gradient and using this in the equation of the line, referenced to ($\bar{t}, \bar{y}$).

(iii) Many full marks here also with the errors being either finding the prediction and not finding a residual at all, or reversing the required order of $y_{observed} - y_{predicted}$.

(iv) Once candidates had found the predicted value, the majority were aware of the dangers of extrapolation and thus gained maximum marks on this part of the question. Those who opted to describe the extrapolation process tended to succeed but a small minority didn't. Comments such as "unreliable, as the point is not in the data set" were not given credit. . Some candidates chose to write about biological, rather than mathematical, reasons for unreliability.

(v) This part, as intended, tested more candidates but there were still many who gained full marks. The most frequent errors in the final equation were either related to excessive accuracy being used or to not stating the equation at all.

Question 2

This proved to be a very straightforward question with most candidates scoring high marks.

(i) Generally well-answered - a minority of candidates not recognising the need to use the binomial distribution, opting to use Poisson instead.

(ii) Generally well-answered, though many candidates included extra information that wasn't relevant.

(iii) Both parts were answered well.

(iv) Generally answered well with most candidates correctly identifying an acceptable approximation using the Normal distribution. The main issues were with not using the appropriate continuity correction or getting the wrong structure.

(v) Not well-answered, with many candidates failing to show sufficient detail in arriving at the given answer. Many seemed to reiterate the given result, merely changing the order of the terms or adding some multiplication signs or just replacing lambda with 0.002n.. Candidates who used lambda rather than 0.002n usually fared better.

(vi) This question was answered well. It was very pleasing to see that the vast majority of candidates used an algebraic approach. Some were let down by poor rearranging skills. A very small minority of candidates used a trial and improvement strategy, with mixed success.

Question 3

There were many good responses to this question, especially on the early parts. Spurious continuity corrections were wrongly applied, throughout parts (i) to (iii), in a minority of scripts - most involving +/- 0.5 but others involving +/- 1. These continuity corrections led to a loss of both method and accuracy marks.

(iA) The majority of candidates correctly standardised the given value then found the correct probability. Some candidates made good use of diagrams to indicate their intent.

(iB) For a question that had potential for many errors, either in standardising, approximating too early, or looking up values incorrectly, this question was answered well. This part was in general done rather better than part (iA).

(ii) The binomial situation, within a question fundamentally on the Normal distribution, was dealt with well by many candidates. The errors that did occur were often about forgetting that (iA) found p(X < 30) whereas this part asked for all five dogs to weigh *more than* 30 kg.

(iii) Few candidates used the wrong tail for this calculation, most correctly identifying that +1.645 was the appropriate value to use as 5% weighed *more than* 30 kg.

(iv) This part of the question tested most candidates. Thus many found dealing with the correct shape and the various relative constraints on the curves difficult. The mark scheme will help with interpretation of the requirements.

Question 4

Most candidates seemed to have been well-coached in successfully finding chi-squared test statistics and applying the test. Hypotheses and final conclusions were generally well-worded and contributions given to an appropriate degree of accuracy. Part b caused the most problems with many candidates being unfamiliar with the techniques for testing for the mean when the population variance was unknown.

(a) Many candidates did very well on this question. The hypotheses were generally correct, though a few candidates referred to correlation. The expected values were generally calculated correctly. The contributions were often calculated correctly but not always shown to three significant figures and sometimes not shown at all. Not all candidates stated the number of degrees of freedom. Most students phrased conclusions correctly but some reached the wrong conclusion from correct values and others were too assertive in their conclusion or failed to put the conclusion in context.

(b) This wasn't as well done as the first part but a lot of good work was seen.
The sample mean was generally found but it not always recorded explicitly. Finding the sample standard deviation caused problems for many candidates; spurious formulae were prevalent and the n-1 divisor often missing. Hypotheses were generally correct though some candidates neglected to define μ; when the definition was provided it was usually in context as the population mean. Few candidates defined μ as the sample mean. The test statistic was usually correctly structured, though accuracy was sometimes lost through inappropriate rounding of the sample standard deviation (often to one significant figure).

Most candidates provided the correct critical value, made a sensible comparison which lead to the correct conclusion. Marks were sometimes lost from a failure to refer to the context in the final conclusion. Overly assertive conclusions and conclusions focusing on the null hypothesis were sometimes seen, but not as frequently as in previous years. Alternative approaches were seen (critical value and probability method) though these tended not to be as well done.

4768 Statistics 3

General Comments

Candidates as a whole found this paper to their liking and scored well on all questions. As in previous years, candidates seemed to be far more comfortable carrying out calculations than with the other requirements of the paper such as producing hypotheses and conclusions, interpreting results and providing definitions. Many scripts suffered from a lack of precision which manifested itself in many ways: inadequate hypotheses; over-assertive conclusions; over-specified final answers yet too little accuracy carried forward in calculations; inaccurate reading of tables; and finally a large number of scripts were very difficult to read. Hypotheses and conclusions are awarded around 15% of the marks available on a paper and yet in many cases they do not receive an appropriate level of care and attention, sometimes appearing at the end of the question or obviously put in as an afterthought squeezed in between lines of working or at the side of the page.

Comments on Individual Questions

Question 1

Sampling and Wicoxon single sample test

This question was very well-done by most candidates and many scored full marks or close to it.

The Wilcoxon test is clearly well understood by most candidates.

Q1ai. was answered correctly by virtually all candidates. The handful who did not score full marks usually did not give integer answers or rounded incorrectly.

Q1aii. The most popular answers here, as expected, were age and gender. Other answers were allowed as long as they led to clear strata and used readily available data. So, for example, subjects studied was not allowed because it would not give clear strata, and parental income was not allowed because the data was not readily available.

Q1aiii. Here the most popular answer by far was that the sample would be representative, although a wide variety of terminology was used. A worthy minority gave the stronger response that stratified sampling also provided information about the individual strata.

Q1bi. A slim majority of candidates were successful here by stating either that there was no information about the background population or that the population was not known to be Normal. The most popular incorrect responses were that the median was known or that it was required to carry out a test on the median

Q1bii. Most candidates realised that the key word was symmetrical. Unfortunately, a minority attached it to ‘sample’ or ‘data’ or ‘the test’.

Q1biii. The great majority of candidates scored at least 8 marks here. If they lost any marks it was almost inevitably in the hypotheses or the conclusion. Most candidates used *m* to represent the population median number of days absent, but many did not use the word ‘population in their definition of *m,* or did not give any context. Some gave their hypotheses and failed to use the word population and thereby lost both marks for the hypotheses. The required conclusion was that there was insufficient evidence to suggest that the median number of days absent had reduced. A number of responses did not include the word median or contained no context. The statement “there is sufficient evidence that the median is still 23” is not equivalent. The test itself is well understood. A handful of candidates failed to subtract 23 and ranked the original data, or ranked actual values rather than absolute values, but these were rare.

Question 2 Continuous pdf and goodness of fit test

Almost all candidates were able to deal with the pdf at the beginning of the question. Goodness of fit tests are clearly well understood by candidates and around half of the candidates scored full marks.

Q2i. Almost all candidates obtained the correct value of k without difficulty

Q2ii. As the answer to this part was given, all candidates got the right answer. Most of them did so correctly. The most common errors seen were algebraic slips and the use of numerical values for the limits of the integral.

Q2iii. The test was done well by the great majority of candidates. The use of 'correlation' or 'relationship' in place of association' was much less common than in previous years in the hypotheses. Most candidates were able to calculate the expected values and the contributions correctly and a pleasingly high proportion of them also realised that the first two classes should be merged. The most common errors involved incorrect degrees of freedom and an occasional use of two-tailed values for the critical value.

Q2iv. 'High contributions because of the model overestimating the frequency for $0 < x < 2$, and underestimating for $3 < x < 4$' is the answer that was expected. A large number of candidates noted the high contributions but did not mention whether there was an under or over estimate. Others listed every class and stated whether there was an under or over estimate, but did not mention contributions. Others gave correct alternative suggestions including the fact that the conclusion of the test would have been different had the classes not been merged or if a 5% level of significance had been used.

Question 3 paired *t* test and confidence interval

Candidates found this question more challenging than the previous two questions. Although the paired *t* test is generally well understood, errors in the hypotheses and conclusions were not uncommon.

Q3i. Most candidates have clearly learned this.

Q3ii. Very few responses simply stated that the underlying population of differences should be Normal and that the sample should be random. Many candidates also included other possible requirements such as 'the sample size should be small' or that 'the variance should be unknown'.

Q3iii. The great majority of candidates knew how to carry out a paired *t* test. Errors in the hypotheses included the use of symbols other than μ, which were then not defined as the population mean, definitions which contained no context, and definitions which did not contain the word 'mean'. Some hypotheses had no definition of terms. Most, but by no means all, candidates were able to calculate $\bar{x}$ and s_{n-1} correctly, although a significant number used truncated values in what followed. The test statistic was usually correctly carried out, although on occasion $\sqrt{10}$ was missing. The majority of candidates then chose the correct critical value of *t,* although occasionally two tailed values were seen, as were values of *z.* The great majority of candidates made the correct decision in terms of rejecting the null hypothesis. A number of conclusions lacked context, some omitted the word 'mean' or were too assertive.

Q3iv. Most candidates know what is expected here, but there were a few errors that were not uncommon. These included the use of a *z* value rather than 1.833 or the use of an incorrect *t* value. A few candidates found a confidence interval for 'with treatment' or 'without treatment' or both. And also a few candidates gave their final interval to 5 or more significant figures.

Answer to 3iv (1.272, 8.588)

Question 4 Linear combinations of random variables

Candidates found this to be the most testing question. The last part of this question provided the opportunity for best candidates to produce some excellent work

Q4i. This part proved to be a good discriminator. Many candidates gave an accurate description of a 95% confidence interval, but a significant minority gave an explanation based on just one interval rather than the population of such intervals.

Q4ii. Although most candidates obtained the correct answers here, this did not seem to be familiar territory for candidates. Many solutions were unnecessarily convoluted. A large number of candidates clearly did not realise that $\bar{x}$ was simply the mid-point of the given interval. Common errors seen were the use of 1.645 instead of 1.96, the use of 20.3 instead of $\sqrt{(20.3)}$, and manipulation errors.

Q4iii. The great majority of the candidates answered this part correctly. The only errors seen were calculating the wrong tail and treating 11.7 and 14.2 as standard deviations rather than variances.

Q4iv. This part posed more difficulties for the weaker students. Some did not deal correctly with the difference between the two distributions being more than 5, and so some ended up in the wrong tail, some with a mean of 8.5 instead of 1.5 and some with an incorrect variance.

Q4v. This question effectively divided candidates into three groups. The first group did not work with means at all and were unable to make any progress. The second group worked with means and so found that the mean of the final distribution was zero. However this group were unable to calculate the variance of the final distribution. What was very common in this group was a lack of explanation as to how they obtained their variance. This lost them the opportunity to gain method marks. The third group, consisting of almost half of the candidates produced excellent, fully correct, solutions.

Answers 4ii $\bar{x}$ = 46.3, n = 90, 4iii. 0.7783, 4iv. 0.3841 4v. 0.1683

4771 Decision Mathematics 1

General Comments

Arguably the most discriminating assessment task is to explain or to justify. This paper had 11 marks allocated to answers that required candidates to write in words, 4 on Q1, 1 on Q2, 3 on Q3 and 3 on Q4. Most candidates were sadly lacking in their ability to do this.

Good written communication and good mathematics go hand in hand. They require the same skills – clarity and precision of thought. At all stages of mathematical assessment candidates bemoan such questions, preferring algorithmic manipulative tasks. The fact is that these writing questions test higher-level skills and understanding … so they are inherently more difficult.

Many candidates lacked physical dexterity in writing, so examiners often had a difficult task just to decode what had been written, before trying to make sense of it. There was a high correlation between readability and sense, but there were some examples of poor readability allied with good sense.

Comments on Individual Questions

Question 1

(i) Many candidates lost one or both marks on this question by confusing tops and bottoms of chairlifts and ski runs.

Many candidates missed the word ‘map’ in the question, and tried to answer subsequent parts by referring to graph theoretic results. They missed the point that, in this part they were being asked to interpret a (bipartite) graph back to reality.

One or two very good candidates shrank the chairlifts to points, and then worked in the resulting directed graph. That was good, but not at all necessary.

(ii) Markers had a fine line to negotiate in awarding or not awarding the explanation marks here. Many candidates gave routes that did involve repetition. But that by itself does not mean that there must be repetition. On the other hand, one has only to say that there are, for instance, two runs served by C, so that C must be repeated. So, for instance, the candidate who stated that having arrived back at the bottom of B, run 5 still remained to be done, with no other details given, would not have been awarded the mark for explaining why B and C have to be repeated.

(iii) Comments as per part (ii).

(iv) The question referred to ‘this information’. Candidates who described the characteristics of bipartite graphs in general, without reference to this specific situation, did not qualify for the mark.

Question 2

(i)&(ii) This question was answered well. Some candidates made mistakes with the arithmetic, but such errors escaped heavy penalty.

Question 3

(i) This question was conceived as an integer programming problem, which is why such phrases as 'no more than' and 'no less than' appear in part (i). With a discrete region the status of the boundaries is important, whereas for a continuous region, that is not the case. In the event, this was lost on nearly all candidates.

Only a minority of candidates realised that for the second mark, there had to be an explanation of how the 75% generated the 1/3.

(ii) Apart from testing understanding and the ability to explain, part (i) was intended to set up part (ii). Very few candidates appreciated this, and very few indeed scored all 5 marks here.

(Strictly, the feasible region should be a set of points, but the few candidates who identified the containing quadrilateral, as identified on the mark scheme, were allowed the mark.)

(iii) It seems an eminently sensible suggestion to purchase 75% of 500 coffee filters and 50% of 500 tea bags, especially since that happens to cost £50. Most candidates failed to score the mark. There really can be no complaints, since invariably they failed to answer the question. They were required to refer to the estimated demand, which was for 500 cups of hot drink per week, and they failed to do that.

Question 4

(a) Routine, and generally well-done.

(b)(i) Routine, and generally welldone.

(b)(ii) That there were 3 marks allocated to this part was a clue as to what was needed: connected, no cycles and minimal. Most scored the connected and minimal marks.

(Note that to prove minimality is taxing.)

(b)(iv) There is not a great demand placed on algebraic skills by Decision Maths, but this found the candidature wanting. Most could not write down $\frac{n(n-1)}{2}-(n-1)$, which was sufficient for the first of the two marks. Many did not appreciate that the first mark was for an algebraic expression and the second for a number.

Question 5

(i)&(ii) Routine and well-done. There were the usual popular errors, mostly relating to the dummy activity, and to slips. The mark scheme was designed so as not to penalise such slips too heavily.

(iii)&(iv) Scheduling questions such as these have appeared in the past and have caused problems. This was no exception. For candidates who appreciated what was required – showing who does what and when, this was difficult enough. But the majority of candidates wasted their time and effort. They could not score any marks because they failed to show who did what and when.

In part (iii) there was a mark for showing when activities C and H were scheduled. That information was needed, although those activities needed no resource.

Question 6

This question was answered very well. Some candidates failed to ignore ‘9’ when they needed to in their F/G/H simulation. Some failed to compute their proportions correctly in parts (ii) and (iv).

Some candidates were confused by the starting conditions … ‘Their last meal out was at the Greek restaurant’. They included this meal in their simulations, despite the instruction ‘… for the next 10 of their meals out’. This was quite an expensive mistake.

4772 Decision Mathematics 2

General Comments

Candidates were well-prepared and dealt well with questions 1, 3 and 4. Question 2, on logic, was difficult. Even then, it was pleasing to see so many show good resilience to give good answers to the final part, even when earlier parts had proved to be problematical.

Comments on Individual Questions

Question 1

(i) Formulations were well-done. Marks were lost by neglecting to say whether the objective was to be maximised or minimised, and by failing to define variables, either adequately or at all. The requirement for variables to be defined as ‘,,, the number of …’ persists, since the phrasing is both required and needed to specify variables precisely.

(ii) The Simplex algorithm was very well-understood. It was no less impressive that candidates could handle the numerical manipulations so well.

(iii) A straightforward question … 3 marks, and most referred to income, production and resources.

(iv) The standard of written work on 4771 was poor, and comments made on that exam report apply here. When challenged to think, rather than apply, candidates were found wanting. Candidates just needed to note that the problem is an integer-programming problem. Instead, much waffling was seen.

Here is an extract from the 4771 comments …

Good written communication and good mathematics go hand in hand. They require the same skills – clarity and precision of thought. At all stages of mathematical assessment candidates bemoan such questions, preferring algorithmic manipulative tasks. The fact is that these writing questions test higher-level skills and understanding … so they are inherently more difficult.

Question 2

(i) This established the theoretical foundation of the question. It was well-understood and answered well.

(ii) Having recounted the story, this modelled the structure of Russell’s argument. Again, it was straightforward, although some candidates failed to indicate the order in which they were applying their operations.

(iii) The requirement to write, again brought problems! Many candidates clearly harboured the perception that *d* had the status of a fixed proposition whose truth value was to be determined. They failed to appreciate that the focus was on the process – that *d* can be correctly deduced from *a*, whatever *d*’s truth value.

(v) Candidates failed to pick up that the answer to this was provided in the question … to establish a deductive sequence (from a false statement to the desired conclusion).

(vi) Again, the requirement to explain (understand?) proved too much of a challenge for all but just one or two candidates. They needed to note that if a true statement appears in the deductive sequence, then only true statements can correctly be deduced thereafter.

(vii) It was very pleasing to see the very large number of candidates who could deal competently with combinatorial circuits.

Question 3

This question was concerned with the same network throughout, but the parts can be grouped by the three problems therein.

(i)-(iv) Shortest paths

Parts (i) and (ii) were found easy. Incorporating the information about the new node caused some problems. In the process some candidates managed to produce correct matrices in (iv), even though they had errors in their drawn network in (iii).

(v)&(vi) TSP

Competently done by many candidates.

(vii) CPP

Many candidates seemed to run out of steam by part (vii). There were few completely correct algorithmic solutions. In the very worst solutions candidate cast around naively looking for a solution, inevitably without success.

Question 4

This was very well-answered. Some candidates made slips in their costings in (ii). Many failed to answer the question in (iii), giving the new best route, and not the value of the information.

The final mark found all but one or two candidates wanting. The mark had to be awarded to candidates who referred to cost. No other answer was allowed.

4776 Numerical Methods (Written Examination)

General Comments:

As usual, there was a lot of good work seen from candidates who have clearly engaged with the specification and who understand the techniques of numerical mathematics. Routine numerical work with standard algorithms was generally carried out accurately – though not always efficiently.

It was notable on this paper that elementary algebra is difficult for some candidates. Q1(iii), Q3(i) and Q5(i) all revealed weaknesses in some candidates' algebraic skills.

Poor presentation continues to be an issue, with illegible hand-writing and a propensity to scatter numerical work haphazardly on the page being far too common. Examiners will always do their best to decipher candidates' work, but sometimes the challenges are insurmountable.

Comments on Individual Questions:

Question 1

The numerical solution of equations is generally done well and this question was no exception. Locating the root in part (i) and showing that the iteration fails to converge in part (ii) presented no difficulties. The algebra in part (iii) defeated some candidates, but almost everyone was able to use the new iteration to obtain the root.

Question 2

Many found this question difficult. In part (i) the best possible estimates for the two integrals come from using Simpson's rule for the first and the mid-point rule for the second. Common errors were to use the trapezium rule or the mid-point rule for the first integral. And some candidates thought that the second integral required the estimation of f(0.6).

In part (ii) the statements made were often vague: 'I would use f(0.6) to get better estimate' or 'I would use Simpson's rule'. Examiners were looking for a clearly expressed understanding that the second integral could now be found using Simpson's rule.

Question 3

A substantial number of candidates appeared to miss the point of this question – perhaps because they didn't read it carefully enough, perhaps because they were not well-prepared for the topic. The key words in the question were 'The program stores and calculates all numbers rounded to 5 significant figures', but a very common error was to work to the full accuracy of the calculator. There *is* a substantial error when intermediate answers are rounded, but this error does not show when full calculator accuracy is used.

In part (iii) the comment required was that the subtraction of the nearly equal rounded values gives rise to the error. Very few candidates stated this clearly.

Question 4

The first part of this question was done well by most candidates. However, the comments on the accuracy of the estimates were often wrong. Many candidates were still thinking in pure mathematical terms and saying that a smaller h will give a better estimate of the derivative. In numerical mathematics – mathematics using limited precision arithmetic – that is just not true. A smaller h will always lead eventually to *less* accurate estimates.

Part (ii) required some judgement as to the point at which accuracy is lost. Answers of 0.24 and 0.237 were accepted.

Question 5

Part (i) of this question required candidates to set up and solve a pair of simple linear equations. This was very straightforward for most, but led some into great difficulty. The second part was a pretty routine exercise in absolute and relative error. The only common problem here was confusion between the exact and the approximate values.

Question 6

Though this question explored a somewhat different take on interpolation, many candidates acquitted themselves well. The sketch in part (i) was easy, as was using the Newton formula in parts (ii) and (iii) to express q as a quadratic function of p. In part (iv) candidates were expected to realise that, as the values of q are not equally spaced, the inverse interpolation requires Lagrange's formula. The only problem was confusion, for some candidates, between arguments and function values.

In part (v) the point was that the inverse interpolation does not give the starting value. There were some simple comments to that effect (for which credit was given), and some that were a little more analytical, pointing out that different approximate methods should be *expected* to give different answers.

Question 7

Showing the existence of the root in part (i) was easy, but showing that there are no other positive roots defeated quite a few. The simplest approach is to show that the gradient of the function is always positive for x positive. Another common method was to locate the single turning point and argue from that to a single positive root.

The sketch in part (ii) was simple enough, but in part (iii) the construction lines for the secant method had to be added and that proved a lot more difficult. It was evident that some candidates were using the false position method. This gives the same values for x_2 and x_3 as the secant method, but they give different values for x_4. This difference leads, in turn, to different construction lines on the graph.

In part (iv) most candidates obtained the correct solution, though not always using the required method. Showing that the required accuracy has been obtained involves checking for a change of sign. Though this is not difficult, many candidates omitted it.

Coursework

General Administration

Centres are reminded that the deadline date for the submission of marks to the board is May10. This is to ensure that a sample request can be generated which will give centres the chance to receive it and despatch the sample to the moderator before breaking up for half term. Most centres complied most helpfully but a number did not, resulting in the receipt of coursework by the Moderator well into June. A few centres sent all the work in good time to the Moderator but failed to submit their marks to the board. Without knowledge of the sample determined by the board, Moderators are unable to proceed which causes the same problem as above. It should be noted that the same comment was made in previous reports and our experience is that there has been no change in this aspect of the moderation process.

However, the despatch of the centre Authentication form (CCS160) was much improved with only a few centres having to be chased by OCR for them. Centres are reminded that the marks will not be validated (and therefore added in to the unit totals) without sight of this form signed by all the assessors.

Assessors are also requested to fill in the cover sheets fully. The loaded marks made available to Moderators are only identified by candidate number. Consequently, when a set of coursework tasks are received by the Moderator which are identifiable only by candidate name then there are difficulties with matching the work with the correct name and number. There was more than one instance when two candidates in the sample had got the same candidate number!

It is helpful to Moderators if comments are made on cover sheets to indicate where marks are being withheld and why. It is also helpful if an annotation is made on the script where the work has been checked. It is disturbing to note that there is a continued issue of assessors ticking work that was incorrect.

Centres are reminded that it is a requirement to supply a brief report on the Oral Communication.

The new MEI unit ‘Introduction to Quantitative methods’ has a piece of coursework not dissimilar to the old Statistics 1 and it is set up with the same marks as the other units. The same team has moderated the work for this unit and a report is included here. Many centres submitting candidates for this unit were new to coursework and the administration was less efficient than in the other units. It is hoped that the experience this year will enable examination officers to follow the guidelines and, if necessary, seek advice on the administration of coursework in good time before next year.

The following comments are made to assist assessors in their task of interpreting the criteria. Most centres were fully conversant with these and it is clear that the task of assessment was carried out with great diligence and professionalism. However, there are a number of centres where the assessor was less well informed and (usually) awarded a mark that was more generous than was justified by the work seen. Centres are encouraged to ensure that all assessors have sight of this (and previous) report to inform them in their work on a future occasion.

4753 – Methods for Advanced Mathematics, C3

There are no new points to be made this series – the task and the assessment criteria have remained unchanged now for some years. Assessors need to note what is being said in the reports.

It is worth repeating what has been written previously. The following points should be subject to a penalty of half a mark.

Change of sign

- Most candidates do a decimal search. The root should be stated (rather than a range being given) and it should be correct to at least 3 decimal places. A number of candidates took, for instance, the range [1.11, 1.12] and asserted that the root was 1.115 correct to 3 decimal places.
- A graph of the function does not constitute an illustration.
- The following equations should not be used to demonstrate failure: trivial equations, equations with a root that is found in the table, equations with no roots. In this latter case candidates sometimes choose a very poor scale on the y-axis (perhaps going up in tens or worse) so that what is happing with a graph near to the axis cannot be seen clearly. Candidates then assert that the graph just touches when in fact it does not. A change of scale will indicate whether it cuts in two places or does not cut the axis at all.

Newton-Raphson method

- The roots should be found to at least 5 significant figures. We expect to see the working for at least one root that demonstrates an understanding of the method. This means seeing the formula developed from the general Newton Raphson formula for the particular equation (including sight of the derived function). Screenshots of 'Autograph' may be used for subsequent roots but does not in itself demonstrate an understanding of the method.
- If an equation is used which has only one root, the second mark should not be awarded.
- As with the previous method, a graph of the function does not constitute an illustration. We expect to see two clear tangents which match the iterates.
- Error bounds need to be established, typically by change of sign, rather than simply stated.
- This method can be shown to fail if an initial value close to one root actually converges to another. Typically, an initial value that is 'close to the root' may be an integer either side of the root. Taking an initial value that is not close enough to demonstrate failure to converge to a stated root is not acceptable. Likewise, we do not expect a contrived initial value just because it happens to be a turning point.

Rearrangement method

- Although there is no stipulation for error bounds in this criterion, nor is there any demand for a specific accuracy; it is expected that candidates will give a specific value for the root, and be aware of the accuracy of their root. It seems reasonable in a numerical process to expect values to be given to at least 3 decimal places.
- A graphical illustration will show either a staircase or cobweb diagram. This diagram should match the iterates found. The magnitude of $g'(x)$ can be discussed in two ways. The gradient function, $g'(x)$ can be found and calculated for a value of x that is close to the root and referred to the criterion for convergence. (The initial value of x is not usually close enough.) Alternatively, the gradient of the curve $y = g(x)$ can be discussed in general terms in relation to the way in which the curve cuts the line $y = x$ (which has gradient 1)..
- The same equation should be used to demonstrate failure. The same rearrangement may be used to attempt to find another root, or a different rearrangement may be used to find the same or another root.
- As with the success, a clear diagram should be drawn to demonstrate divergence using the iterates found and the value of $g'(x)$ discussed.

Comparison

- When making a comparison of the fixed-point methods, the same initial value should be used to find the same root to the same degree of accuracy.
- Without this, the discussion of speed of convergence is not valid. It is expected that the number of iterates required in each method to find the root should form part of this discussion.
- Candidates should refer to the hardware and software available to them in working this task. Different candidates will have different resources and will come to different conclusions.

Terminology

- Many assessors give the full mark here regardless of the terminology used. Typical errors which should be penalised are: failure to write equations (referring, for instance to y = f(x) as an equation), incorrect language (for instance "I am going to find the root of the graph") and candidates who word process their reports but are unable to write subscripts and powers properly.

4758 – Differential Equations

All those using a modelling task, marked under scheme A undertook 'aeroplane Landing'. Centres are strongly advised to note comments made on this task in previous years – the same errors in assessment are occurring leading to a scaling of marks. The following points are repeated.

- Some candidates reject their initial model on the basis of the first nine seconds. The second phase of the motion, which should be investigated fully, before proceeding, is ignored. It is not valid to make a judgement on the suitability or otherwise of a model without testing the model for the whole motion
- It is expected that, when comparing the predicted and observed data, both table and graphical forms should be used.
- Curve fitting must be avoided, for instance, when air resistance is considered to be proportional to vn and the value of n is found which provides the best fit.
- The assumption that air resistance is proportional to v2 is often stated, but on many occasions no attempt is made to justify this assumption. If, for example, this or other assumptions are found in 'a book' or 'on the internet' then references should be given.

When undertaking a modelling / experimental task (marked under Scheme B), care must be taken to avoid circular arguments. This occurs if only one set of data is produced. A model is created, and the data are then used to calculate parameters that are then used to predict the same data for comparison. The preferred method, for example in 'Paper Cups', is to use a set of observations for say one cup to predict the outcomes for say 5 cups or so.

A common example of curve fitting is assuming that the flow out of a container is proportional to hn and then finding the value of n which provides the best fit to the data.

4776 – Numerical Methods

The vast majority of candidates submitted tasks on numerical integration. Most candidates selected appropriate problems, but a few didn't express them well, or did not explain why they were appropriate. Assessors did not always penalise accordingly. The following points have continued to be issues because assessors are not penalising appropriately.

- Most used a sensible strategy, but often the justification for the selection of the algorithm was sketchy or non-existent. The criteria demand not so much an explanation as to how the three methods work but why they are being used.
- In the Formula application domain, a small minority only went as far as 16 strips.
- A few candidates inadvertently made an error in entering their function into the spreadsheet and therefore evaluating a different integral to the one stated. It is expected that assessors will note this and penalise accordingly.
- Nearly all used a spreadsheet well, but many missed the point of the second mark in the Technology domain, and were given credit for either describing which software they used or just printing out the formulae. They are expected to explain how the algorithm was implemented – usually by annotating the spreadsheet cell formulae. Many did the right thing here, but left the reader to work out what had been done by scrutinising the spreadsheet. Some detail is expected in the commentary!
- A few mistakenly extrapolated from early values of Simpson's Rule and achieved a less precise answer than their previous best estimate. A few used extrapolated values of M and T to obtain S – this is not valid and a penalty should be applied. Only a few used external sources – such as a value for π to inappropriately find relative error. This should not score – but it was sometimes given full credit.
- In the final domain some candidates did not give a definitive statement of what they considered to be their best answer, so they should not get the first mark. Six significant figures is not the aim of the coursework but a guideline – candidates should give the best answer they can from their working, and justify the precision quoted from their error analysis. Weak candidates tend to quote all the figures from their extrapolated value as "the answer". Mediocre candidates tend to be very conservative and say they are confident with the 6 significant figures they quote (and often as many as 10 significant figures are quoted). Many only gave limitations of the spreadsheet - which is not usually relevant. Few commented on r or problems with estimating undefined values of the function such as 00.

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