STEP Examiner's Report 2013

Mathematics

STEP 9465/9470/9475

October 2013

Contents

STEP Mathematics (9465, 9470, 9475)

Report	Page
STEP Mathematics I	**3**
STEP Mathematics II	**8**
STEP Mathematics III	**11**
Explanation of Results	**14**

STEP 1 2013 Examiners’ Report

General Comments

Around 1500 candidates sat this paper, a significant increase on last year. Overall, responses were good with candidates finding much to occupy them profitably during the three hours of the examination. In hindsight, two or three of the questions lacked sufficient ‘punch’ in their later parts, but at least most candidates showed sufficient skill to identify them and work on them as part of their chosen selection of questions. On the whole, nearly all candidates managed to attempt 4-6 questions – although there is always a significant minority who attempt 7, 8, 9, … bit and pieces of questions – and most scored well on at least two. Indeed, there were many scripts with 6 question-attempts, most or all of which were fantastically accomplished mathematically, and such excellence is very heart-warming.

Comments on individual questions

[Examiner’s note: in order to extract the maximum amount of profit from this report, I would firmly recommend that the reader studies this report alongside the *Hints and Solutions* supplied separately.]

Q1 This question is all about using substitutions to simplify the working required to solve various increasingly complicated looking equations. It was the most popular question on the paper, essentially attempted by every candidate (as is the intention). The obvious pitfall of not realising that the square-root sign indicates the “non-negative square-root” of a quantity was clearly flagged at the outset. Thus, the only remaining hurdle to fully complete success lay in the need to check the validity of solutions once found. The mean score on this question was 14/20, and this question thus represented a successful *entré* to the paper for almost everyone.

The use of the quadratic formula and the method of completing the square appeared in almost equal measure throughout the question, although a significant minority of candidates opted to rearrange and square in both (ii) and (iii). This was not a major obstacle to success in (ii) but led to a quartic equation in (iii) with which few candidates knew how to make successful progress. The final hurdle for most candidates lay in a final justification that any roots found (up to four of them, depending upon the method chosen) were genuinely valid. It is very easy to explain, without the use of direct verification, that the two roots found via the substitution method are good, but very few candidates made any attempt to justify their results.

Q2 This was another very popular question, attempted by more than a 1000 of the candidates. The initial difficulties arose in the interpretation of the *integer-part* (or *floor*) function. Candidates’ graphs revealed the difficulties and uncertainties associated with the use of such a function. In particular, the lack of “jumps” at the endpoints of each unit interval was very prevalent, and many candidates effectively assumed that the function is an *even function*. There was also considerable uncertainty in how to represent whether endpoints were “in” or “out” – the usual convention being closed dots for “included” and open dots for “not-included”. Also, many candidates failed to show in their sketch that the function was zero in the interval $0 \le x < 1$, and others drew straight line segments instead of portions of a reciprocal curve in each unit segment. Pleasingly, however, (at least from the candidates' point of view), it was possible to get quite a few of these bits wrong and still go on to answer correctly many of the following parts of the question. Thus it was that the mean mark on the question, at 9/20, was still a respectable one.

In parts (ii) and (iii), it was only necessary for candidates to realise with which portion of the function they had to deal in order to be undertaking the correct algebra, and the ten marks allocated to these parts of the question were generally those from which the majority of candidates were scoring the bulk of their marks. Only the very last part of the question required much thought, and candidates were not helped by an unwillingness to set down in writing any of their underlying thoughts, merely opting for statements that seemed to come from nowhere obvious. It was unfortunate that some considered the function to be defined only on the interval $-3 \le x \le 3$, which was simply that required for the sketch.

Q3 This vector question was actually very straightforward, though its unfamiliar appearance clearly put most candidates off, with only around 350 of them making an attempt at it. There were nine marks available for the first two parts, which were technically undemanding, and it is no coincidence that the mean score on the question was around 9½/20. I suspect that, for the most part, this was considered by candidates to be one of those questions that are done towards the end of the examination in order to bump up their paper total by getting the easier marks at the beginning of the question, with no real intention of making a complete attempt. Candidates usually gave up part-way through (iii) where a stab at the "corresponding result for $X * (Y * Z)$" was required of them, which was actually just $(X * Y) * (X * Z)$. I imagine this highlights the lack of students' familiarity with such properties as distributivity when considering binary operations.

Q4 This was another very popular and high-scoring question (attracting over 1200 attempts and with a mean mark of more than 10/20). The first part to this question involved two integrals which can be integrated immediately by "recognition", although many students took a lot of time and trouble to establish the given results by substitution and surprising amounts of working. Those candidates who had found these easy introductory parts especially troubling usually did not proceed far, if at all, into part (ii). Those who did venture further usually picked up quite a lot of marks.

One of the great advantages to continued progress in the question is that the two integrals in part (ii) can be approached in so many different ways – the examiners worked out more than 25 slightly different approaches, depending upon how, and when, one used the identity $\sec^2 x = 1 + \tan^2 x$; how one split the "parts" in the process of "integrating by parts"; and even whether one approached the various secondary integrals that arose as a function of $\sec x$ or $\tan x$. This meant that, with care, most of the marks were accessible, although many candidates clearly got into a considerable tangle at some stage of proceedings. The most common "howler" was the mix-up between the definite integrals (i.e. numerical values) given in (i) and their associated *unevaluated* indefinite integrals (i.e. functions) which formed part of a subsequent integral.

Q5 This question was usually found to be amongst candidates' chosen six, attracting almost a thousand attempts, though on the whole it produced the lowest mean score of the popular pure maths questions, weighing in at under 7½/20. The initial attraction of the question was undoubtedly the obvious "circle" nature of the given quadratic form when $k = 0$, meaning that part (i) was very familiar territory. Unfortunately, there were very few marks allocated to this bit. Part (ii) drew a lot of unsuccessful work, especially as candidates seemed ill-inclined to extend the requested factorisation from that of $3x^2 + 3y^2 + 10xy$ into that of the full quadratic expression. Even amongst those who did make that extra step, there were relatively few that grasped the geometric consequences of the result that $AB = 0 \Rightarrow A = 0$ or $B = 0$ meant that the solutions amounted to a line-pair. The question's demand for a sketch of the solutions meant that most of the marks were only awarded for candidates who had made this geometric interpretation.

Part (iii) was the genuinely tough part of the question, but substantial help was offered to enable candidates to make a start on it, which most duly employed. However, working forwards and backwards through the given substitutions did not make for easy reading and it was clear that many candidates did not realise the given locus of Q is that of a standard parabola. Several marks were gained by most candidates, but few made a thorough fist of it.

Q6 Although this question attracted a few more attempts than Q3, it was the lowest-scoring of the pure maths questions. Confident use of the sigma-notation is clearly in short supply and this was, perhaps, that feature of the question that deterred most candidates from attempting it. Also, many attempts were simply from those candidates cherry-picking the opening three marks for proving the standard "Pascal's Triangle" result, mostly by proving it directly from the definition of the binomial coefficient in terms of factorials (which we had decided to allow when setting the paper). This almost invariably accounted for 3 of the 6.7 marks gained on average for the question as a whole.

Those who proceeded further than this opening result generally fell into a couple of very wide traps: a careless handling of the terms at the ends of the series (which, being 1, could be replaced by other binomial coefficients that were also 1) and a failure to consider odd and even cases separately. A final obstacle, were one needed, lay in the oversight of establishing the validity of the relationship between the B_n's and the F_n's for their starting terms – surprisingly, many candidates failed to evaluate B_0 and B_1 correctly.

Q7 Around 1300 candidates attempted this question, making it the second most popular question on the paper. It was also the second highest-scoring question on average which, if nothing else, pays tribute to the candidates' ability to spot the right questions to attempt. In hindsight, this was possibly a little too straightforward; this was undoubtedly partly due to the appearance of similar questions (on what are known as *homogeneous* differential equations) in recent years' STEPs, but also to the fact that part (ii) could be solved by the use of the given approach for part (i). It was part (iii) that required of candidates a stretch of the imagination – the use of $y = ux^2$ – but even this helped make the question more approachable, as this substitution could also be used to solve part (ii) if it turned out that candidates got imaginative a bit earlier than anticipated.

For those making essentially correct attempts at parts (ii) and (iii), the only final hurdle to complete success lay in the hoped-for statement of a domain for the functions which had been found as solutions. We allowed as obvious the taking of non-negative square-roots (since the given "initial" values of y are positive – though, in general, candidates should be encouraged to state that they recognise they are doing this) but expected candidates to indicate a suitable interval for the x values in each case: the hint lay in the given answer to part (i).

Q8 Almost 1200 candidates made an attempt at this question, making it fourth favourite, and the mean score on it was 9.3/20 which, if nothing else, suggests that it wasn't quite as easy as folks considered it to be. To begin with, there is a lot to do for the relatively few marks available, and minor slips over domains and ranges subsequently proved quite costly. Apart from the obvious errors from those candidates who thought the order of composition occurred the other way around, and the few who took "ab" to mean the product of the functions a and b, the usual slip-ups were: thinking that $\sqrt{x^2} = x$, when it is actually $| x |$, and not realising that the domain of the composite function fg is just the domain of g. In (ii), although the functions fg and gf *look* the same (both are $| x |$), their domains and ranges are different: fg has domain $\mathbb{R}$ and range $y \geq 0$, while gf has domain $| x | \geq 1$ and range $y \geq 1$.

A lack of a clear grasp of the domains and ranges of h and k in part (iii) was partly responsible for the poor sketches, although the ability to recognise the asymptote $y = 2x$ was also widespread. There were even occasions, when sketching the curve for k, that a correctly drawn asymptote was subsequently labelled as $y = -2x$ simply because of its appearance in the quadrant in which x and y are both negative.

Q9 This question was the most popular of the applied questions, drawing well over 500 responses, and the most successful of the mechanics questions, with an average score of 8.8/20. It proved to be a surprisingly good discriminator, giving a good range of marks. The use of constant-acceleration formulae for the projectile motion provided a routine and straightforward start to the question, but this was followed by the momentum equation for the collision, which proved trickier, with quite a few candidates getting to $mu\cos\alpha - Mv\cos\beta = Mw_B - mw_A$ but no further. A lot of candidates resorted to writing down the result $mu\cos\alpha = Mv\cos\beta$ without any attempt to justify it. The second result then found many candidates going round in algebraic circles, and very few indeed managed to find the answer (not given) to the very final part of the question.

Q10 This question proved to be the least popular question on the paper, eliciting a mere 150 responses. The mean score of 7.7 on it was almost entirely drawn from the first six marks allocated for obtaining the given result, and then for setting $v_n = 0$ in the following part. This does raise the thorny issue – during the setting process – of the extent to which (intermediate) answers should be given in the question, as candidates clearly find great comfort in having something to work towards, but are otherwise surprisingly weak. Here, for instance, almost any tiny slip-up in working, signs, etc., inevitably had disastrous consequences for a candidate's prospect of successful continuation with the work and very few indeed progressed much beyond the first result.

Q11 A combination of some obviously tricky trigonometry and inequalities meant that this mechanics question was both unpopular and low-scoring, despite the given answer in (i). Only 300 candidates attempted it, and they averaged a score of 5/20, with most of the marks being scored at the beginning with correct statements regarding the resolution of forces vertically and horizontally. In (ii), it was important for candidates to realise (a fact clearly indicated by the question's wording) that the condition $W > T\sin(\alpha + \beta)$ would no longer hold; those that recognised the change in the kinematics did not have too much trouble in working the problem through to its end. However, there were too few who had made it to the end of (i) intact, and these candidates had given up already without proceeding into part (ii).

Q12 This probability question drew more than 350 responses, scoring just over half-marks on average. There are many ways to go about part (i), of varying degrees of sophistication: those opting for elaborate tree diagrams tended to be the least successful. The final part of (i) was really intended as a test of whether candidates realised that this is the same situation viewed “in reverse”, so the answer is the same. Very few candidates spotted the symmetry argument or got it correct by longer methods. Those who had obtained the given result of (i) by one of the more sophisticated methods had little difficulty in employing a similar argument in (ii), although some did mix up the roles of the n and the k. A few did the general method and then substituted particular values. Those who did use a general approach here then fared very well in part (iii) and they usually went on to apply Stirling’s approximation correctly.

Q13 After Q10, this was the least popular question on the paper, and supplied the poorest average score on the whole paper of only 2½/20. I have little doubt that the principal reason for both these factors is the lack of any helpful structure or given answers within the question. Essentially, this problem is that of the set-up for a game of *Solitaire*, but stripped of its context. In this game, when a standard pack of playing cards, suitably shuffled, is laid out at the start, there are seven piles of cards, and each pile has its final card face up. This particular question is looking for cards of the same colour (red or black) and denomination (number or J, Q, K and Ace), giving the 26 pairs. This was, of course, entirely by-the-by as far as candidates were concerned.

Unfortunately, most attempts at this question were abandoned very early on as candidates realised they didn’t really know what to do. Surprisingly, very few even took the trouble to note that the defined discrete random variable X could only take the values 0, 1, 2 or 3. Following attempts to work out the probability for any these outcomes almost invariably consisted of a jumble of fractions and factorials but without any obvious plan to them, and certainly without any explanatory indicators as to what might actually be intended. Only $P(X = 0)$, being the easiest of the four cases to evaluate, was calculated with any degree of success by any of the candidates who attempted the question.

STEP 2 2013 Examiners' report

All questions were attempted by a significant number of candidates, with questions 1 to 3 and 7 the most popular. The Pure questions were more popular than both the Mechanics and the Probability and Statistics questions, with only question 8 receiving a particularly low number of attempts within the Pure questions and only question 11 receiving a particularly high number of attempts.

1. This was the most popular of all of the questions. Overall part (i) of this question was well answered, although there were a number of candidates who were not able to find the tangent and intercept even in this first case. Very few attempts at part (ii) of this question involved the use of sketches. While many attempts at part (iii) recognised the link in the final part with part (ii) of the question, many of the explanations in this section were not well enough explained to gain full marks. In the final part it was pleasing to note that many candidates realised that the conditions implied that the intersection with the y-axis was at a negative value.

2. This was the second most popular question on the paper and the average score was half of the marks. Despite the instruction in the first part of the question to use a substitution a significant number of candidates chose to use integration by parts to establish the result. There were some sign errors in the integrations, but most candidates managed to reach the final result in the first part of the question. The second part of the question was found to be the hardest, with induction the most popular method, although the process was often not fully explained. The final part of the question did not appear to be too problematic for those that reached it. However, algebraic mistakes, such as factors disappearing, resulted in some marks being lost. Similarly, mistakes in the arithmetic in the final part of the question were not uncommon.

3. This question was again popular and had an average score of about half of the marks. In the first part almost all candidates were able to sketch the correct shape of graph, but some did not provide suitable explanations to accompany these or included additional cases that were not asked for. A number of candidates attempting the second part of the question reached one of the results by squaring an inequality without considering the signs and many assumed that the result of part (i) implied that c must be negative. Only about half of the candidates attempted part (iii), and many of those who did did not use sketches in their solutions. Solutions to part (iv) generally involved guessing of the values of a, b and c followed by a check that the conditions were met.

4. This question received a relatively small number of attempts compared to the other Pure Mathematics questions. On average candidates who attempted this question only received a quarter of the marks available. Some candidates did not manage to write down the correct equation of the line or did not appreciate that the phrase "unit radius" means that the radius is 1. Many candidates produced loci for the second part of the question without any indication of a method. In the final part of the question the significance of the restrictions on the value of b were not appreciated by many of the candidates.

5. This was one of the more successfully attempted questions on the paper and the Pure Mathematics question with the highest average mark. While some candidates struggled with the application of the chain rule throughout this question, many were able to complete the first part of the question without much difficulty. Showing that f satisfied the required conditions in part (i) was generally well done, but the sketching of the graph was found to be more difficult, with a number of

candidates not identifying the asymptotes and some thinking that part of the graph would drop below the x-axis. Most of the candidates who attempted part (iii) found the roots of the equation successfully, but a large number forgot to exclude the roots when solving the inequality. In the final part, many identified x=3 as a solution, but those who split the fraction into two equations (one for the numerator equalling 343 and one for the denominator equalling 36) did not check that the solution worked for both parts. Those who used the symmetries established in part (i) were then able to identify the other roots easily, while those who attempted algebraic solutions for the other roots were generally not successful.

6. The algebra required for the first part of the question proved to be quite challenging for a number of candidates, but most were able to reach the required answer. The proof by induction in the second part of the question was generally well done, although a number of candidates did not write up the process clearly. In the final part of the question it was clear that many candidates had identified the relationship between the sequences and Fibonacci numbers and some candidates therefore stated that the limit would be the golden ratio, but without any supporting calculations. In the final part there were few responses which clearly explained that the new sequence would still satisfy the conditions required if it were started at a later term.

7. This question was attempted by a large number of candidates, only slightly fewer than question 2, and was one of the more successful ones with an average score above half of the marks. While some candidates proved the converse of the required result, part (i) of the question was generally done well, although a surprising number of candidates did not write down the numerical solutions when asked. Those students who realised the way to write x and y in terms of m and n reached the result of part (ii) easily, while others sometimes spent a lot of effort on this making little or no progress. In part (iii) many candidates spotted the difference of two squares, but some did not realise that there would be two ways to factorise b^3. Only very few students were able to solve the final part of the question.

8. Candidates attempting question 8 generally received either a very low or a very high score. Many attempts did not progress further than an attempt to sketch the graph and identify the rectangle to be used. There were also some attempts that confused the line $y = f(t)$ with a transformation of the curve $y = f(x)$. In the second part of the question there were some difficulties with the differentiation of $g(t)$, but those candidates who successfully completed this section did not in general have any difficulties with the remainder of the question.

9. The average score on this question was below a quarter of the marks as a large number of attempts did not make progress beyond the first few steps of the solution, achieving just the marks for the resolution of forces required in the first part of the question. Many candidates forgot some of the forces involved and very few decided to take moments. Some of the more clever solutions took moments about one of the contact points, which removes the need for one of the steps resolving forces.

10. This was the least popular of the Mechanics questions. The first part of the question was generally well answered and many candidates were able to apply the result of part (i) to the particular case identified in part(ii). Part (iii) was found to be more challenging, but some candidates did manage to provide a convincing argument for their answer.

11. This was the most popular of the Mechanics questions and also the most successfully answered question on the paper with candidates scoring on average three quarters of the marks. Candidates appeared to be very comfortable with the concepts of conservation of momentum and the law of restitution and were able to progress through the series of calculations required without too much difficulty. There were some errors in the algebra, but the majority of candidates were able to work through accurately to the end of the question.

12. This was the least popular of all the questions. Many of those who did attempt the question succeeded in calculating the expressions for the expectations, but the simplification of the calculation for the variance proved more tricky. A good number of the candidates managed to reach the final part of the question, but few were able to provide a valid argument for the final result.

13. Many candidates were able to complete the parts of the question that related to the early cases, but some struggled to generalise the expressions for the probabilities in the cases required in part (iii) of the question. Of those that reached the correct expressions many struggled to establish the required relationships between them.

STEP 3 2013 Examiners' report

With the number of candidates submitting scripts up by some 8% from last year, and whilst inevitably some questions were more popular than others, namely the first two, 7 then 4 and 5 to a lesser extent , all questions on the paper were attempted by a significant number of candidates. About a sixth of candidates gave in answers to more than six questions, but the extra questions were invariably scoring negligible marks. Two fifths of the candidates gave in answers to six questions.

1. Most candidates attempted this question, making it the most popular and it was also the most successful with a mean score of about two thirds marks. The first two standard results caused few problems, nor did the integration, but some struggled to simplify to the single inverse tan form. In the final part, common errors were failure to reduce to the $n = 0$ case, confusion with the index e.g. $I_n + 2I_{n-1} = \int_0^{\frac{1}{2}\pi} \sin^n x \, dx$ instead of the correct result, or for those that were more successful, algebraic inaccuracies let them down. Some attempted a recursive formula to evaluate $\int_0^{\frac{1}{2}\pi} \sin^n x \, dx$ with varying success. Most attempting the last part saw the connection between I_0 and the main result of the question.

2. This was the second most popular question, attempted by six out of every seven candidates, with only marginally less success than its predecessor. The first differential equation was proved correctly and many successfully completed the general result by induction, although there were some problems with the initial case. Some had difficulty finding the correct coefficients for the odd powers of x in the Maclaurin series but the last part produced a variety of errors and few correct answers. Such errors included $\sin^{-1}\frac{1}{2} = \frac{\pi}{3}$, forgetting to divide y by x , and attempting to evaluate the series using $x = 1$.

3. A seventh of the candidates attempted this, making this the second least popular Pure question, though with on average, half marks being scored, it was the third most successful of the Pure questions. Some candidates found the scalar product of $p_1 + p_2 + p_3 + p_4$ with itself to obtain the stem correctly, whilst some found its product with p_1 or p_i , in which case they did not always appreciate the importance of symmetry. Part (i) caused few problems. Part (ii) saw a few errors with consideration of $\pm$ signs, though some candidates used geometric considerations and then rotations correctly to obtain the results. The last part separated the sheep from the goats.

4. Just over two thirds of candidates attempted this with moderate success, approximately one third marks. Most succeeded with the opening result but even so, some lacked full explanation. Whilst most wrote down the correct form for the roots, few correctly expressed all the roots in the given range. Surprisingly, there was very limited understanding of the connection between the roots and the factors of $1 + z^{2n}$ so the general result was not well answered. Conversely, part (i) was well-answered with the exception of those who did not deal with the powers of i satisfactorily. Part (ii) was beyond most candidates mainly because they failed to cancel the factor $1 + z^2$. However, those that managed to deal with this aspect generally answered the whole question very well.

5. Nearly as many attempted this as question 4, but only achieving a quarter of the marks making it the least successfully answered question. Almost all missed the point of the question given in the first sentence, and made other assumptions, which frequently only applied to primes rather than integers in general. As a consequence, most did not satisfactorily justify their results.

They generally fared better tackling the second part of (i), though some tried to prove the statement in the wrong direction. They approached (ii) better though few gave a valid argument why $p^n \leq n$.

6. About half attempted this with marginally more success than question 4. Many candidates tried to write $z = x + iy$ or similar and likewise for w and then tried to expand which involved a lot more work than dealing with conjugates directly. Some tried to use the cosine rule rather than the triangle inequality from the diagram. In general, the first result and parts (i) and (ii) were well done but only the strongest candidates did better than pick up the odd mark here and there in trying to obtain the inequality. A lot of mistakes were made mishandling inequalities, but even those who could do this correctly overlooked the necessity of substantiating that th4 square roots are positive and that the denominator is non-zero.

7. Three quarters attempted this with more success than question 6 but less than question 3. Sadly, it was not uncommon for candidates to fail to differentiate $E(x)$ correctly. Many established that $\frac{dE}{dx} = 0$ but then $\frac{d^2y}{dx^2} = -1$, when $y = 1$, $\frac{dy}{dx} = 0$, and $x = 0$ giving a maximum which was not sufficient and missed the point of the squared $\frac{dy}{dx}$ term in $E(x)$, with consequences for the rest of the question. Many followed the stationary points line of logic correctly by considering the maximum and minimum values in part (i). Having established the constant value of $E(x)$, some candidates attempted to solve the differential equation, usually by incorrect methods. The errors of part (i) were largely replicated in part (ii). There were fewer attempts at part (iii), and a number fell at the first hurdle through not obtaining the correct $E(x)$. Further, numerous candidates assumed rather than proved that $5\cosh x - 4\sinh x - 3 \geq 0$.

8. A seventh answered this question, making it the second least attempted question scoring a third of the marks possible. The first result evaded many candidates who did not identify and calculate the geometric progression, although a few did employ the fact that the sum of the roots of unity is zero. The result for s caused few problems and was for many candidates the only success in the question. Those that attempted the length of the chord were comfortable with the algebra of trigonometry namely $\cos(\theta + \pi) = -\cos\theta$, and $2\cos^2\theta - 1 = \cos 2\theta$. There was mixed success with completing the final result.

9. About a fifth attempted this, with the same success as question 7. Common errors were false attempts for the volume at the beginning using hemisphere and cones, and in the last part approximating x small rather than $x - \frac{1}{2}R$ small. Many candidates were successful as far as the equilibrium but couldn't deal with the small oscillations successfully.

10. The number of candidates attempting this was almost identical to that attempting question 3 with marginally more success making it the third best attempted question. Most obtained the moment of inertia correctly, and many found the angular velocity correctly. Provided that they had correctly applied conservation of angular momentum, and Newton's law of elasticity, they almost all worked out the required result. Some attempted to use conservation of linear momentum whilst others did not use conservation of angular momentum correctly. Most then knew how to differentiate, but many made computation errors. Even if they got the correct quadratic equation at the end, many solve d it wrongly. Very few showed that the feasible solution did indeed generate a maximum.

11. A fifth of the candidates attempted this question, with marginally less success than question 3. Most that attempted this question managed to achieve the first two results successfully, unless they got the diagram wrong. However, the final result was found trickier as some forgot to include the gravitational potential energy, some failed to evaluate the correct elastic potential energy and there were many mistakes made handling the surds.

12. This was the least popular question, attempted by a ninth of the candidates, with slightly less success than question 8. The immediate problem was many made no mention of probabilities in order to calculate expectations. Throughout, there was very poor justification, which included treating the random variables as though they were independent and compensating errors which led to given results. Most progressed no further than part (a) of (ii) at best and many had $E(X_i) = \frac{ab}{n^2}$.

13. The number attempting this was very similar to that attempting question 3 with the same level of success as question 11. In general, candidates attempted both parts of (a) correctly, and then likewise part (i) of (b) then stopped. However, part (b) (ii) tripped up many. Some successfully dealt with part (iii) without having managed (ii).

Explanation of Results STEP 2013

All STEP questions are marked out of 20. The mark scheme for each question is designed to reward candidates who make good progress towards a solution. A candidate reaching the correct answer will receive full marks, regardless of the method used to answer the question.

All the questions that are attempted by a student are marked. However, only the 6 best answers are used in the calculation of the final grade for the paper.

There are five grades for STEP Mathematics which are:
S – Outstanding
1 – Very Good
2 – Good
3 – Satisfactory
U – Unclassified

The rest of this document presents, for each paper, the grade boundaries (minimum scores required to achieve each grade), cumulative percentage of candidates achieving each grade, and a graph showing the score distribution (percentage of candidates on each mark).

STEP Mathematics I (9465)

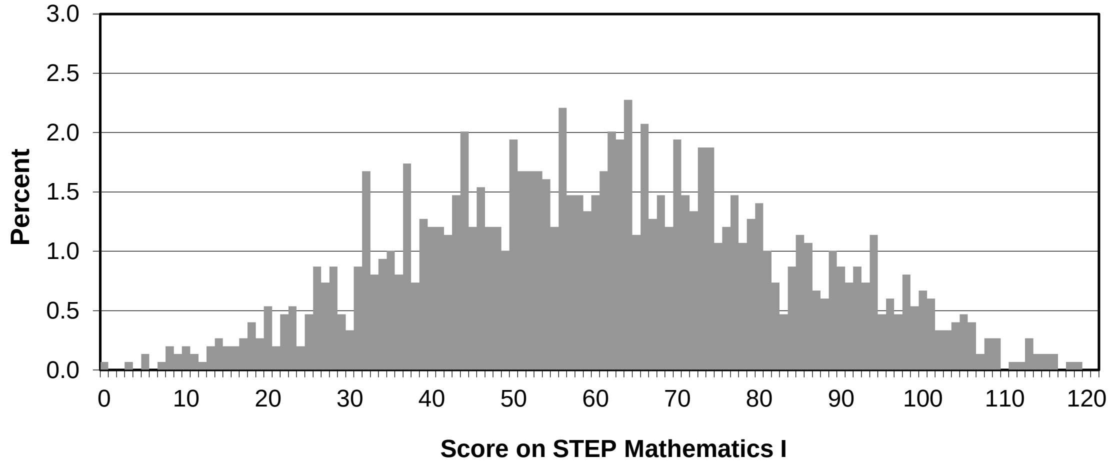
Grade boundaries

Maximum Mark	S	1	2	3	U
120	100	82	64	40	0

Cumulative percentage achieving each grade

Maximum Mark	S	1	2	3	U
120	4.8	18.6	45.0	81.6	100.0

Distribution of scores



STEP Mathematics II (9470)

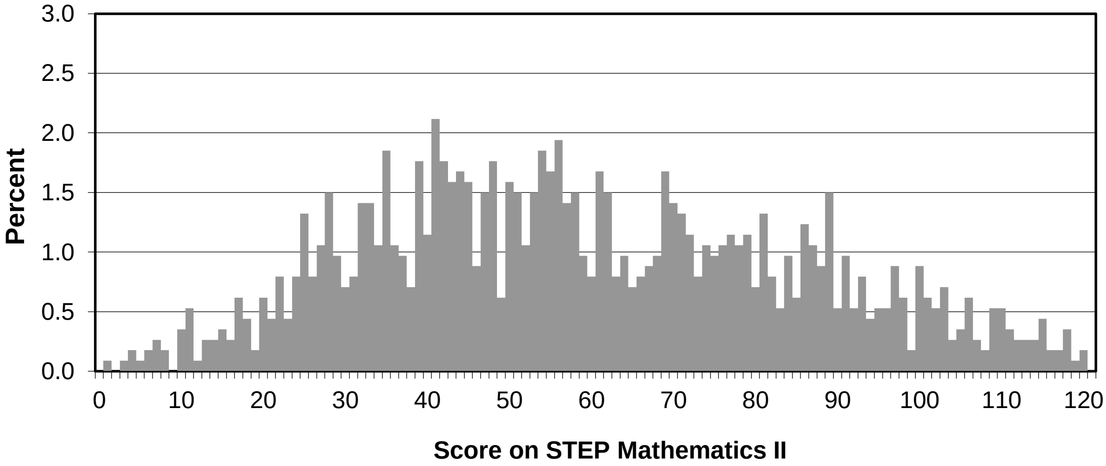
Grade boundaries

Maximum Mark	S	1	2	3	U
120	100	79	67	32	0

Cumulative percentage achieving each grade

Maximum Mark	S	1	2	3	U
120	8.0	24.8	38.3	85.4	100.0

Distribution of scores



STEP Mathematics III (9475)

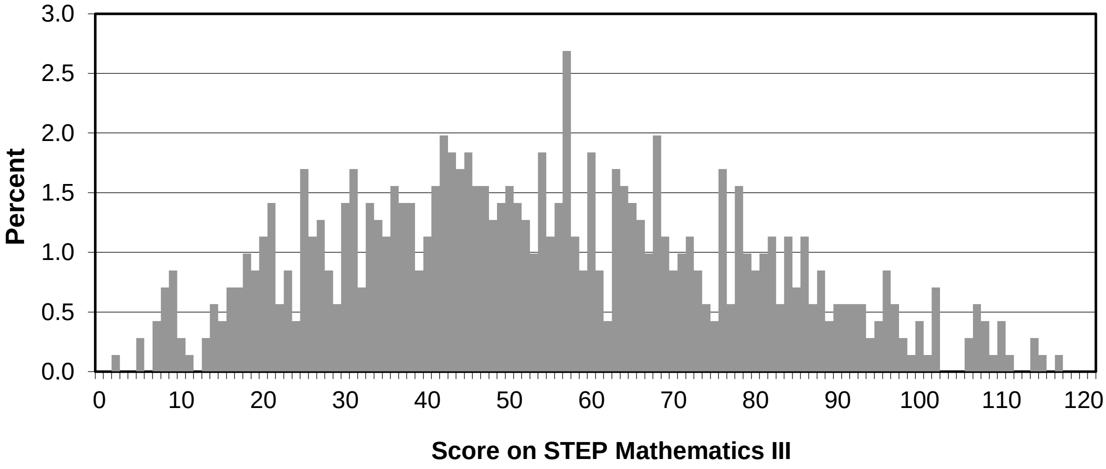
Grade boundaries

Maximum Mark	S	1	2	3	U
120	85	63	48	27	0

Cumulative percentage achieving each grade

Maximum Mark	S	1	2	3	U
120	12.3	36.6	56.7	85.4	100.0

Distribution of scores



The Admissions Testing Service is part of Cambridge English Language Assessment, a not-for-profit department of the University of Cambridge. It offers a range of tests and tailored assessment services to support selection and recruitment for governments, educational institutions and professional organisations around the world. Underpinned by robust and rigorous research, its services include:

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- behavioural styles assessment
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