



Examiners' Report  
Principal Examiner Feedback

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In Decision Mathematics D1 (WDM11) Paper 01

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## Introduction

The paper proved to be accessible to almost all candidates, with many able to gain high marks on at least three of the first four questions. The final four questions differentiated well, challenging the most able candidates and producing a good spread of marks.

A key piece of advice to candidates is to ensure that they read the demands of the question carefully and to ensure that they use a complete method to obtain their solution, showing all their working. Many candidates lost marks by failing to show sufficient working. This was particularly true where candidates were asked to show a result given in the question. Candidates must also realise that if a question asks them to give to give a reason for their answer, then they are expected to write a brief explanation.

### Question 1

This standard question on bin-packing and sorting proved to be accessible to almost all candidates. They recognised what was required and appeared well drilled in carrying out the necessary processes. It was good to see many well presented solutions, which helped candidates avoid the careless errors often seen previously.

(a) The majority of candidates gained all three marks for the correct first fit bin pack. The most common error was to pack 5 into the third bin instead of the second. A few candidates failed to realise that 10 could pack in the first bin, consequently losing all three marks.

(b) Many candidates gained full marks with almost all using middle right pivots for this quick sort. Bubble sorts were rarely seen, scoring M0. Only a few candidates found just one pivot per pass, or mixed middle left and middle right pivots, for both of which the mark was M1 only, losing three marks. It was rare to see failure to maintain the correct order of values either side of pivots. The most common error was omission of the final pivot leaving the list (10 5) without a pivot, thus losing the final mark. Ascending sorts were penalised two marks for a misread.

(c) The first fit decreasing bin pack was done well, with many getting both marks and almost all achieving at least M1. Occasionally candidates used five bins with 28 in bin 4 and 26 in bin 5, consequently losing both marks. Only a few repeated or omitted a value.

## Question 2

This question combined the use of Dijkstra's algorithm and the Route Inspection algorithm, with the latter using some results from the former. Most candidates were able to apply both algorithms successfully, although many had small errors in the working.

(a) There were many really good attempts at this part, with most gaining full marks. The ordering within the working values were where most candidates who lost marks made errors: 231 was often missing from E, 245 often appeared before 217 (or was the final value), not sufficient/incorrect working values at C. There were also errors seen in the working values at J.

(b) The vast majority of candidates correctly paired odd nodes, but candidates rarely accurately found totals for each repeated route. A number of candidates did not write totals for all of the pairings, losing multiple marks from not correctly following the algorithm, despite understanding the process. It was clear many had not realised that they could use values from part (a) to help them to get the correct lengths of the paths for each pairing.

(c) This part was the poorest attempted, frequently blank. A minority of candidates worked out that CE was to be repeated but did not go on to state "finish at J". End points were offered with little, if any, justification. A sizeable majority thought that an arc containing A should be chosen!

## Question 3

This should have been a relatively straightforward question, which was not answered well by a very large number of candidates.

(a) Almost all of the mistakes came from failing to follow the flowchart correctly, most commonly candidates on the return loop would erroneously go back to the  $c = ab$  box and recalculate a new value of  $c$  that then disrupted their further work. Consequently many candidates only scored one mark, despite clearly putting effort into the question. For those who followed the flowchart accurately there was often a pleasing level of accuracy to pick up the first three marks. A large number of candidates then forgot to write the answer on the output line. Some candidates used decimal approximations instead of exact fractions, which was not penalised. A small number of candidates incorrectly entered a numerical value in cell **h** before they had obtained the final output.

(b) Given that relatively few candidates achieved the correct final value in part (a) there was very little chance of the others being able to describe the purpose of this algorithm. A good proportion of those with the first three or four marks did pick up the last mark but, interestingly not many stated Lowest Common Multiple. Instead they tended to use a more long-winded equivalent description.

#### **Question 4**

This question was generally completed much better than in previous series, with many clear diagrams seen. However, there are still a number of candidates who did not draw a sufficiently large diagram for their working to be clearly seen, or who drew the arrows at the end of activities or dummies, so that these merged with the nodes. Candidates should ensure that arrows are drawn on the middle of activities or dummies. They should also ensure that dummies are drawn with clear dotted lines.

(a) There were some really pleasing, well drawn diagrams from a large number of candidates. Activities (and dummies) were clearly labelled and arrowed and many candidates picked up all 5 marks here. The most common error was forgetting the fifth dummy for the uniqueness of J/K or missing one or all arrows on activities. There was still the odd candidate who had no arrows on dummies and gained only one mark and some who drew activity on node diagrams and scored no marks. A small number of candidates used additional, unnecessary dummies or failed to have a single end point.

(b) This seemed to confuse candidates and there were not many correct answers seen. Common incorrect answers were just A, H – seeming to focus in just on D, and at a more sophisticated level A, B, F, H – missing out activity C and not seeing from their own diagrams that it directly precedes F (via a dummy) which is itself a direct predecessor of I. Some candidates even labelled their activities with their lengths (1 or 2) but still failed to identify all the critical activities.

#### **Question 5**

Here candidates were guided through the process of setting up a linear programming problem. It proved to be a good discriminator between abilities, with the full range of possible marks awarded. Candidates must be aware that if a question asks for the objective, this consists of two parts, the statement maximise or minimise and the objective function.

(a) Many candidates lost the first mark, omitting to state “maximise”. Candidates should be advised that “maximum” is not the correct word to be used here and is therefore penalised. Most were able to write down the correct objective function. Occasionally the function was then erroneously multiplied by ten, so losing the mark. In this situation mark schemes never allow for such subsequent working to be ignored.

(b) Setting up the inequality, given in the question, proved to be particularly challenging to the majority of candidates, with many making no attempt. The minority quickly produced the sum of the three fractions correctly setting it to be less than or equal to one. Some gained one mark working with ratios, but were unable to link these to produce the given constraint.

(c) Many candidates attempted this part of the question gaining 1 or 2 or, rarely, 3 marks. It was most common to see errors with the  $3y \leq 2z$  inequality, either with the symbol in the wrong direction or the coefficients transposed. Sometimes the other two inequalities were left with four terms rather than being simplified to three terms, or left with non-integer coefficients. A small number of candidates, having obtained a correct, simplified inequality, went on to make a further incorrect simplification, which was penalised. A few candidates scored no marks when failing to rewrite the percentages as decimal or fractional equivalents.

## Question 6

Most candidates were able to attempt this question, but had differing degrees of success.

Many candidates were unsuccessful in part (a) or simply did not attempt this part of the question. Of those attempting the question, the first mark was often obtained, but the majority of candidates did not mention that solutions to the Travelling Salesman Problem must return to start. A small number gave correct details but the wrong way round.

Part (b) was often answered well, but some candidates did not number their Prims on a table and made errors when writing down chosen arcs, thus losing marks that could otherwise have been gained. Quite a few responses incorrectly began AB, BC, CD... accompanied by 1 2 3 4 ... on the top of the matrix. Some candidates still insist on drawing out the arcs rather than listing them. A small number of candidates started at a node other than A and were penalised and some confused Prim with the Nearest Neighbour algorithm and incorrectly added an additional arc to return to A.

Part (c) was usually answered well, with the majority of candidates doubling the weight of their Minimum Spanning Tree. However, those candidates who had made errors in (b) were also penalised here.

In (d) candidates occasionally forgot that the Nearest Neighbour algorithm returns to starting node. Some also failed to read the question correctly, just giving the length of the Nearest Neighbour route, without actually stating their route, which was penalised.

In (e) many candidates realised that it was the shorter upper bound that was the better one and stated this with a reason.

Part (f) was usually answered well by candidates, though often they did completely new working for this and did not take advantage of their prior work to answer this efficiently. Candidates could have noticed that just two marks were available for this part, suggesting that a shorter method than a RMST was possible.

Part (g) was usually answered well provided candidates had mostly been successful in earlier parts. The most common error was using a strict inequality for the upper bound and often the mark was not scored due to earlier mistakes in the question.

## **Question 7**

Most candidates made a reasonable attempt at this question, although many were inaccurate with their work in part (b), which had consequences for the later parts of the question. Candidates must take care to ensure that all their top boxes are increasing in value when working from the start to finish and that all their bottom boxes are decreasing in value when working backwards from the finish to the start. In (e) candidates would be advised to use a ruler to draw their cascade diagram and to ensure that they use clear shading to identify floats.

(a) Many candidates did not attempt an answer, or did not make a clear enough mention of the activities Q and R in relation to the idea of uniqueness, or not being able to have the same start and end node. Many candidates struggled to use correct terminology here and the benefit of the doubt was given to those who were able to write a statement which gave the sense of uniqueness.

(b) The four marks were divided into the entries for top and bottom boxes respectively, and the majority of candidates gained both marks for the top boxes. However, the bottom box at the end of activity A and at the end of activity C, were often completed with values greater than the bottom box at B, which lost both the method mark and accuracy mark for the bottom boxes. Candidates also frequently made errors in the bottom boxes across the bottom row of the grid.

(c) Most candidates got the correct critical activities of A, F, I, L and P, however because of the errors in labelling of the early bottom boxes, there were a notable number of candidates who selected B instead of A as a critical activity, which impacted this mark as well as the later cascade diagram.

(d) Although this was a standard float calculation, a number of candidates were perhaps unsure of the requirements of the question and attempted a calculation based on the length of the critical path and compared this with the length of activities C H K M P. While this did give the correct answer, some candidates did not show this correctly. Candidates who performed the standard float calculation showed their working very clearly, with only a small minority unable to do so. The main reason for the accuracy mark being lost was an error in the bottom box at the end of activity K, which resulted in an (incorrect) value of 4 instead of the required 3. A small number of candidates carried out a calculation here to find a lower bound for the number of workers required. These candidates must ensure that they read the question carefully.

(e) Those candidates with minimal errors in part (b) tended to complete a fairly accurate cascade chart. Only a very few chose to draw a scheduling diagram. Those candidates with an incorrect set of critical activities in (c) alongside errors in the bottom boxes, struggled to gain the accuracy marks available. Some candidates did not draw their float particularly clearly, or did not shade it, which made it challenging to award accuracy marks, and the lack of ruler use meant some candidates answers were challenging to decipher, or that they ran out of room, despite the ample space available.

(f) A significant number of candidates did not attempt the final part of this question, however those that did frequently identified the correct 5 activities (D, E, F, G and H), stated that 5 workers were required and gave a time in the interval from 12 – 13. However, in order to gain the accuracy mark they needed to be clear that it was during day thirteen, and the time interval needed to be a strict inequality, so as not to include the 12 or 13, which was where many candidates made an error.

## Question 8

Blank responses were not uncommon which may well have been caused by candidates running out of time, which was also indicated where some answers stopped abruptly in the middle of a potentially good solution. Up to five marks depended on the solution of simultaneous equations. Candidates should ideally have calculators with this functionality and be able to confidently use them. There is now no requirement to show working other than the exact answers, preferably along with the equations to be solved.

(a) Many candidates gained both marks. The errors most often seen were either strict inequalities or  $y \geq 3x + 4$  instead of the correct inequality direction. Of those that attempted this very few failed to achieve any marks. Some candidates decided to rearrange the equations given in the question to make  $y$  the subject of each, before converting these to inequalities. There was no requirement or advantage to do this, and, in some cases, the rearrangement introduced errors.

(b) The majority of candidates attempting this part scored the first three marks for solving the correct pairs of simultaneous equations to calculate the coordinates of the maximum and minimum points. Some wasted time unnecessarily finding the coordinates of all four intersection points. Those legitimately using their calculators to solve their equations saved time compared with those showing their extensive written working. A small number of candidates gave their solutions as decimal approximations. While this was not penalised here, this inevitably caused an error with their subsequent working. The next two marks proved elusive for some, though a good proportion did create their two equations based on  $P = ax + by$  and progress to solving them simultaneously. It was not unusual to see attempts using  $y = ax + b$ , for the objective function, which was penalised with the loss of both marks.

(c) Many candidates made no attempt here. The correct answer (3,11) was rarely seen by examiners, with (3,10), (2,11) and (8,8) being quite popular incorrect alternatives, as well as occasional non-integer solutions or answers outside the feasible region. Many candidates seemed unaware that an integer solution for a minimum point must be above the constraints. A small number of candidates showed very clear working here, considering the four integer points around the minimum point.

