Examiners' Report
Principal Examiner Feedback

Summer 2023

Pearson Edexcel International Advanced Level
In Decision Mathematics (WDM11/01)

Introduction

This paper proved accessible to the candidates. The questions differentiated well, with most giving rise to a good spread of marks. All questions contained marks available to the E grade candidates and there also seemed to be enough material to challenge the A grade candidates.

Candidates are reminded that they should not use methods of presentation that depend on colour but are advised to complete diagrams in (dark) pencil. Furthermore, several candidates are using highlighter pens even though the front cover of the examination paper specifically mentions that this type of pen should not be used.

Candidates should be reminded of the importance of displaying their method clearly. Decision Mathematics is a methods-based examination and spotting the correct answer, with no working, rarely gains any credit. Some candidates are using methods of presentation that are very time-consuming; they are reminded that the space provided in the answer book, and the marks allotted to each section, should assist candidates in determining the amount of working they need to show. Some very poorly presented work was seen and some of the writing, particularly numbers, was very difficult to decipher. Candidates should ensure that they use technical language correctly. This was a problem in questions 2(a), 5(b) and 7(d).

Report on Individual Questions

Question 1

This proved to be a successful opening question accessible to almost all candidates with most scoring well. Most candidates gained all four marks in part (a) with fully correct early and late event times. The most common errors were incorrect late times at the end of activity B and/or activity C. The calculations of the float and lower bound in parts (b) and (c) were generally correct, with correct working shown. Many candidates had gained full marks to this point but only a minority achieved this with the schedule in part (d). Inevitably some made no attempt, or just completed the critical activities. The modal mark was 1 (out of 3) as many candidates attempted a schedule with just three workers, perhaps to match their lower bound. Errors were commonly associated with activities N or Q, either being omitted or extending beyond 33. However, a good number of candidates were able to produce a perfect schedule using four workers. A substantial minority of candidates constructing a cascade chart which gained no credit.

Question 2

Part (a) was a good discriminator for understanding the quick sort algorithm. Many candidates simply identified the middle item, 28, as the pivot, having apparently failed to read the question carefully. Of those who identified 13 almost all gave a correct explanation referring to both sides of the list. There were few errors in part (b) with the bubble sort though it was quite common for the necessary fifth pass to be omitted, with the loss of the final mark. This final pass is required to complete the algorithm and comments like “stop” or “sort complete” are insufficient. Those candidates who mistakenly sorted in ascending order lost two of the three available marks, even if they then reversed their answer. Candidates should be advised that, at this level, they must sort in the order specified in the question. Most candidates gained full marks for the bin-packing in part (c). The most often seen error was in failing to place the 6 in the second bin, putting it in the third bin instead.

Question 3

This question provided a good spread of marks and was accessible to most candidates.

One of the difficulties with unseen algorithm questions is the fact that the algorithm can vary quite substantially (in both application and difficulty). However, most candidates were able to at least attempt the algorithm in part (a), obtain a correct first row and complete sufficient iterations in order to earn at least the method mark. The overwhelming majority of candidates were in fact able to complete the first few rows accurately with the most common errors being either a line of zeros in the fifth row of the table, or no zero at all in the fifth row. Another error which arose on a few occasions was a ‘43’ in the B column of the second line, perhaps suggesting that candidates were unsure how to apply the INT function (even though several examples of this function had been provided in the question).

For some candidates, it seemed that space was something of an issue and those candidates who wrote one number per line, quickly ran out of space and either stopped or drew their own makeshift table on the question paper.

Following completion of the table, candidates tended to be less successful with the rest of the question. Often the output was incorrect, with common incorrect answers including a single digit ‘4’, an extra ‘0’ e.g., ‘7 1 2 4 0’, or, in some cases, this part was left blank.

Part (b) required candidates to explain how the output related to the input and surprisingly this part was often left blank. Many candidates who did attempt this part of the question, believed that the question was asking how the output at each stage related to the new value of N at each stage and so gave explanations along the lines of ‘the output is the last digit of N’. Others tried to explain the INT function. Many candidates were looking for something more deeply mathematical than the 'input reversed', and it was rare to see a candidate succinctly express that the output was the digits of N in reverse order.

Question 4

This question was a good source of marks for candidates who were well prepared for the steps involved in solving a graphical linear programming problem.

Part (a) required candidates to obtain the constraints for a linear programming problem from the graph of the feasible region. The equations of two of the lines were given and candidates were expected to find the third equation and convert all three equations into inequalities. This was generally well-attempted. There were, as expected, the usual errors in directions of inequality signs, use of strict inequalities and some errors in calculation of the gradient for the third line – it was evident from some gradient calculations that some candidates seemed to believe that the line passed through the origin.

In part (b) candidates were asked to find the vertices of the feasible region and almost all candidates were able to write down the vertex (6, 12). However, a significant minority of candidates believed they were being asked for the coordinates of the points inside the feasible region, rather than the vertices of the feasible region. Those who did find the correct three points, usually did so with ease, often making use of their calculator to solve the equations to find the other pairs of coordinates.

Part (c) was where a significant number of candidates failed to realise that in the point testing method <u>all</u> vertices of the feasible region must be tested in the objective function. A sizeable number of candidates used the objective line method and therefore did not evaluate P at all three vertices.

Part (d) was challenging for many candidates and so discriminated well. Candidates who substituted (6, 12) and (20/3, 10) into the objective function and solved an inequality for k were the more successful. Those who attempted a gradient approach sometimes came unstuck and were often confused by the negative signs and/or the direction of the inequality symbols. Often candidates also considered the comparison of the objective function at (6, 12) and (5/2, 5) and therefore obtained both $k > -1$ and $k > 2/3$. In these cases, it was common for candidates to neglect to conclude that ‘therefore $k > 2/3$’ and so often the final mark in this part was lost. Other errors included comparing the objective function in terms of k with ‘48’, the optimum value of the objective function for the case when $k = 3$.

Question 5

Almost all candidates attempted the activity network in part (a), most of whom gained at least three marks. The specification requires activity on arc, so the small minority doing “on node” lost all five marks. The majority tried to construct a diagram conforming to the precedence table (often using extra dummy activities). It was quite common for just the final mark to be lost due to superfluous dummy activities, or failure to have a single finish. Candidates should be advised to carefully check their completed diagram for labels and arrows on all activities, and arrows on dummies. Examiners commented that arrows are best drawn midway along arcs rather than at the end, almost concealed, on a node. Many candidates gained one of the two marks available in part (b). There were frequent instances of calculations with no explicit link to the problem, for example "33 – 10 – 8 – 7 = 8" with no mention of activity K, which could score only one mark even if the result J < 8 was correctly stated. Some candidates who did have (duration of) K = 8 then deduced that J > 8, clearly misinterpreting the concept of the critical path.

Question 6

Most candidates were able to apply Dijkstra's algorithm correctly in part (a). Occasionally working values were omitted (e.g., one of the three values at C, or the 67 at J) or incorrectly included (e.g., a value of 48 at H). Sometimes there were errors in order of labelling, especially with duplicate labels, such as a 1 at A and B, or a 3 at D and C. Both marks for the shortest path and its length were gained by many candidates. Part (b) was less well done. Many candidates failed to recognise that the endpoints C and E, coupled with A and J, created the situation of the required odd node pairings, consequently losing all marks in this part. Of those who did attempt route inspection relatively few had the three correct totals, partly because they did not make use of their final values from part (a). Often the shortest length 52 was correct, but 84 was frequently seen instead of the required 82. Candidates' answers to parts (c) and (e) were varied and often left blank, with only a minority gaining either or both marks. The answer to (d) was dependent on the method marks in (a) and (b) so this limited the potential for this mark.

Question 7

In part (a) (applying Prim's algorithm) it was not uncommon for candidates to lose at least one or two marks here for failing to state the arcs in the minimum spanning tree in the correct order, or for missing at least one of the required arcs. Candidates are advised, when applying Prim's in tabular form, to write down the arcs at the same time as numbering the nodes at the top of the table as it seems that a correctly labelled tableau is often not translated to a correct list of arcs after the fact. Strangely, it was not uncommon for candidates to add an extra arc to the end of their list, usually CA, to 'return to A' – perhaps a confusion between Prim's and the Nearest Neighbour algorithms. Another common error was picking FG as the third arc of their MST (again, potentially a confusion with nearest neighbour).

In part (b) many candidates realised the need to double the weight of the minimum spanning tree to find the upper bound although some believed that they needed to add the weight of arc CA instead.

The Nearest Neighbour algorithm in part (c) was often more successfully attempted than Prim's in part (a). However, as is often the case, candidates neglected to write down the final step of returning to A, even when they clearly included the weight of this final arc in their sum. Others omitted this step in both the route and the sum, giving an incorrect answer of 212. Other candidates did not list any arcs at all, giving only a sum of arc lengths, despite having been specifically asked for the route in the question. There were a significant minority of candidates who decided, incorrectly, to double the length of their nearest neighbour route to find the upper bound, such errors had implications for the following parts of the question.

In part (d) candidates were given a nearest neighbour route starting from a different vertex, E, and asked to determine which of the nearest neighbour routes gave a better upper bound. Candidates were expected to refer to the initial stem of the question where a range for *x* had been given and to use this to determine the highest possible value for the upper bound from E. This was often well attempted; however, many candidates did not engage with the range of values for *x* and instead made general comments about smaller upper bounds being better which did gain any credit. Others, because of earlier errors such as incorrect upper bounds from A of 212, were unable to access marks here as they too did not engage with the range of values for *x*. Of those that did attempt to consider the different values for *x*, some considered the lower end of the range for *x* which demonstrated a lack of understanding of the need to choose the upper bound which is as small as possible at its greatest value.

Part (e) was rarely successfully attempted. It was surprising how few candidates used the ‘235’ for the lower bound given in the question in order to set up an equation for *x*. Rarer still were those candidates who realised that they could obtain the weight of the residual spanning tree by subtracting the weight of arc AH from the weight of the tree found in part (a). Those who were successful in establishing and solving a correct equation for *x*, were mostly successful in writing down a correct range for the optimal length of the tourist’s route. Occasionally the final mark was lost for an incorrect strict upper limit to the bound.

Question 8

This question proved to be a challenging end to the paper for many candidates, perhaps due to time constraints, or perhaps due to the limited scaffolding in the problem.

Part (a) required candidates to express the linear programming problem in terms of *x* and *y* only. Most candidates attempted to set up the problem in terms of *x*, *y* and *z* although the majority stopped there. The most common incorrect inequality was $5z \geq 2x$. This often had the 5 and the 2 transposed or, in a few cases, the inequality sign reversed. In some cases, this was written with *x* and *y* instead of *z* and *x* e.g. $2x \geq 5y$.

Converting the problem into constraints proved challenging for many, especially the relationship between academic and leadership prizes which was very often incorrect. The objective function was often omitted or confused with the cost constraint as many candidates seemed to feel they should be minimising cost. Unfortunately, and critically for further progress in the question, many candidates misinterpreted the constraint for the proportion of sports prizes as an inequality rather than an equation. This meant that if an attempt was made to eliminate z, it was often an arbitrary choice which inequality constraint would be converted to an equation to conduct the elimination with. This meant unfortunately that often significant amounts of algebra were churned through to no avail as an incorrect equation had been used.

In part (b) there was the possibility of accessing the marks even if full progress had not been achieved in part (a). For those who had ignored the request to eliminate z in part (a) could now do so using $y = 16$, and therefore $z = 64 - x$, provided they had two or three correct constraints from part (a). Furthermore, those candidates who had performed accurate work eliminating z from the constraints in part (a), but who had no objective function, were able to make progress here and could potentially earn both marks in this part. Nonetheless, part (b) was not well attempted and was often left blank. Most commonly, candidates converted the constraints to equations and were able to obtain $z = 24$ but without earning any credit for doing so as they had neglected to use the constraints to deduce the key range for x, the solution for x, and the corresponding number of leadership prizes.