Pearson Edexcel

Examiners' Report
Principal Examiner Feedback

Summer 2023

Pearson Edexcel GCE

In A Level Further Mathematics (9FM0)

Paper 3D Decision Mathematics 1

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Introduction

This paper proved accessible to most candidates although examiners noted that a significant number of candidates are still struggling to cope with the new content not previous seen in the legacy D1 and D2 modules, and some had difficulty with the problem-solving nature of some of the questions (which forms part of the assessment objectives for this qualification). However, 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 was also enough material to challenge the A grade candidates.

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. 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 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 1(a), 1(c), 4(a) and 4(e).

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.

Report on Individual Questions

Question 1

Part (a) was generally well answered with most candidates identifying ‘neither’, and giving a suitably correct reason. A few candidates showed a lack of understanding, saying the graph was Eulerian because it had an even number of odd nodes. Furthermore, some candidates gave definitions for Eulerian and semi-Eulerian graphs without stating why graph G was neither.

Part (b) was mostly correct with only a small number of candidates not returning to their starting node (when stating their Hamiltonian cycle).

Although part (c) was generally well answered there was a good number of candidates who stated that the graph could be drawn without arcs crossing but did not actually demonstrate this (by drawing the graph as planar) or explain how it could occur (e.g., by stating that AC should be moved ‘outside’).

Most candidates in part (d) stated the correct answer of 2 but a significant number of candidates stated 4 in this part.

Examiners noted that very few incorrect answers were seen to part (e) but where they did it was usually a lack of infinity symbols (in cells AD, CE, DA and EC) or a simple slip on one or more of the values.

Most candidates in the final part achieved full marks but some made simply arithmetical slips (often having a 10 instead of 9 or a 13 instead of 12).

Question 2

This question proved accessible to most candidates. The most common error was a 3 as the late time at the end of activity A. As the resource histogram, in part (b), is an addition to the new linear specification, it was pleasing to see that most candidates were able to make a reasonable attempt at this part, at least gaining the initial method mark, for a plausible answer correct up to time 4. Many responses were then also correct up to time 8, gaining the second mark. Some candidates did struggle to complete the histogram correctly, with various errors seen between times 8 and 11. As a result, they had an incorrect time interval for the final mark.

Question 3

Part (a) was generally well answered, with common errors being that not all attached nodes were updated every time a new node was considered. A few candidates, it would seem, still fill in the working values at the end of the process (leading to several errors), but nearly all showed the necessary replacement of working values (which is the key to this shortest path algorithm). The most common error was that node D was frequently overlooked when node C was the node being actively considered. There were very few issues with the order of labelling (of the nodes) reported by examiners.

When applying Dijkstra's algorithm, and specifically the updating of the working values, we cannot stress enough that candidates should **never** cross out any of their previous working values as it is often very difficult for these values to be read. It is vital that examiners can read these values as these alone provide the complete evidence that the algorithm has been applied correctly.

Most candidates scored at least one mark in part (b), but often not both. While most responses indicated that the candidates understood that a ratio of the two values for n was required, many did not convert appropriately from seconds to minutes. There was a minority of candidates who incorrectly concluded that $n(n^2)$ implied that a cubic ratio of the two values for n was required.

Question 4

This question was accessible and was attempted by most candidates, most of whom earned at least some marks.

Part (a) was generally well done with the majority gaining the mark. In previous series, with similar questions, candidates have been seen to assign a value to the unknown, x, at the outset but this was very rarely seen this series. A variety of valid approaches were employed such as comparing the total of the numbers (excluding x) to the capacity of 3 bins; comparing the total of the numbers (including x taking its lower bound value) to the capacity of 3 bins; determining the required size of x if the numbers were to fit into 3 bins followed by a deduction that x would need to be negative and, less commonly, arguments based on the fact that four numbers had a magnitude that was at least half the bin size. Candidates should be reminded that their reasoning should always be specific to the question and the values given in the question, rather than more general statements which cannot be given credit. Those candidates who attempted arguments based on bin-packing were often less successful and rarely gained the mark.

Part (b) was also generally well attempted with nearly all candidates finding at least one critical value and earning at least one mark, and most earning both marks. Many gave correct equivalent ranges such as $24 \leq x \leq 28$ or $23 < x < 29$. Common errors involved the strictness of the inequality with answers such as $23 < x < 28$. A minority of candidates gave the incorrect range of values as $23 < x < 40$, which did not take account of the fact that the numbers could fit into four bins. Others lost a mark for only stating one end of the range of values for x e.g. $x \leq 28$.

The application of bin-packing in part (c) was done well with very few errors seen. When errors did occur, they were usually due to slips rather than misconceptions in the application of the algorithm and most candidates earned either two or three marks in this part. The most common error seemed to arise from a belief that only four bins could be used and in these cases the '13' was placed in bin 3 with the 'x' and the '4', or the '4' was placed in bin 2 with the '9', '23' and '5' (even though this gave a bin size of 41). Cumulative totals were rare and only occurred as an apparent slip in one or two cases. "First-fit increasing" was also thankfully very rare. A minority of candidates repeated a digit (usually the '4' or the '5') which cost them the final two marks. A very small number of candidates assigned a value to x which limited the number of marks that could be achieved.

Most candidates were well-prepared for the quick sort in part (d) and most earned at least some of the four available marks. The question was accessible to almost all candidates with the extreme value x being the middle of the eleven items making the initial method mark very achievable. Common errors included inconsistency in the choice of middle-right or middle-left pivots, re-ordering numbers during a pass (commonly swapping the 3 and the 4 on the second pass), omission of the sixth pass, sorting into ascending rather than descending order, or very occasionally, the choice of a pivot for the first pass which was not middle-left or middle-right. Miscopies were rare, and values were lost from one pass to the next in only a minority of cases. The layout of candidates' sorts was sometimes quite difficult to follow when the fixed value was not rewritten in subsequent passes. This was somewhat better when candidates drew vertical arrows, but candidates should be reminded that their solutions should be set out as clearly and logically as possible to avoid their own slips and to enable examiners to see the application of the sorting algorithm. Candidates employing a 'slow-sort', involving one pivot per iteration, were very rare as were applications of a Bubble sort.

In part (e), candidates who had found the correct upper bound for x in part (b) were usually successful in identifying 28 as the correct value of x. However, there were some errors seen in the manipulation of inequalities and some candidates incorrectly stated that $x + 15 < 40$ and $x + 13 < 40$ and so concluded that x = 24 or x = 26. Where x = 28 was achieved, the justification for this value was often clearly given, but sometimes there was little reference to why '27' was a critical value. Many candidates attempted to place items into bins, but many omitted the 13.

Question 5

Part (a) proved discriminating as many candidates were unable to identify the correct four nodes which needed pairing for the given route, instead choosing C, D, G and J. For those that were able to identify that F needed to be considered rather than J, the overwhelming majority scored full marks in this part. A minority of candidates did not fully list the arcs to be repeated.

Part (b) was generally well answered, with a good number scoring full marks. Many candidates were able to accurately apply Prim's algorithm, but some candidates worked solely on the table, and did not follow the instruction to state the order in which arcs were selected which lost them the final accuracy mark. A minority of candidates used a version of the Nearest Neighbour Algorithm to generate a spanning tree. Several candidates found the weight of their MST which was not required for part (b), although it could be used when finding the RMST later.

Part (c) was answered well by most candidates. A minority did not complete the tour by returning to G, either failing to close their tour or by returning to A. Mistakes were made in using this to calculate an upper bound some multiplying the length of the route by 2.

Part (d) proved more challenging and was not attempted by a significant number of candidates. Very few candidates recognised how they could adapt their MST from (b) to answer (d) efficiently and instead found the RMST again (and this was often done incorrectly). This was one of the parts of the paper most likely to be left unanswered by candidates with a significant number moving on once part (c) was completed. Those candidates who found the correct RMST tended to score both marks.

For part (e) many candidates did not recognise the need to state the route in terms of the actual towns visited. Some candidates gave a partial route, quite a few wrote a sentence explaining about the need to go to each town rather than explicitly stating the route, and others gave a lengthy explanation in words which did not meet the demands of the question. Again, this part was not attempted by a large proportion of candidates.

Question 6

In almost all cases, candidates understood that activities should be on arcs rather than nodes and that the network should have a single source node. As a result, almost all responses scored some, if not all, of the available marks. The general structure of the graph was usually correct but errors in the use of dummies were often the cause for a loss of marks. The inclusion of surplus dummies was not uncommon (usually at the end of activity A or D or E). Some candidates seemed reluctant for arcs representing activities to either bend or intersect other arcs which therefore seems to explain the inclusion of extra, unnecessary dummies. From time to time, candidates missed the uniqueness dummy at the end of activity I (or J). A minority of candidates omitted a single activity, usually H, or failed to show arrows on all activities. A more costly error was to omit arrows on dummies. Occasionally, networks did not have a single sink node where candidates failed to bring the ends of activities H, K and L together. A minority of candidates drew multiple copies of almost identical graphs, usually not making much if any improvement from one to the next and in some cases producing less accurate networks due to miscopying. It seems to be very costly in term of time to be producing multiple networks and candidates should be advised to focus on a single accurate network.

Part (b) was answered correctly in all but a small handful of responses. Part (c) by contrast was far more of a challenge and was frequently left blank. Many candidates were unsuccessful in identifying the relevant values for the window in which activity F could occur, with many incorrectly assuming the latest F could finish was at time 16. The most common incorrect duration stated was ‘2’ which was probably more common than the correct value of ‘4’.

Part (d) was not answered well by many candidates and proved to be a good discriminator. There was confusion evident in both parts with incorrect values being used in many cases. For the float of activity K, a reasonable number of candidates correctly identified the interval 19 – 24 and knew that this interval was shared between the float and activity length. A common error was assuming that the length of activity J influenced this in the stated maximum case, despite the question stating that it should be in terms of y.
For the float of J, few candidates identified the correct interval from 12 – 24, with a common error using the earliest finish time of activity D or the end of activity I. Other incorrect answers involved incorrectly using the float of activity K rather than the duration of K e.g. $24 - 12 - x - (5 - y)$.

Question 7

Almost all candidates attempted this question, though it seemed that some ran out of time part way through. Only a few candidates gained full marks. There were several common mistakes occurring in candidates’ responses to part (a). These were: failing to state “maximise” when defining the objective function, failing to convert the 150 and 60 hours to 9000 and 3600 minutes when defining the constraints, and writing the constraint “at least three times as many paperbacks as hardcovers” incorrectly as $3x \geq y$ rather than $x \geq 3y$. Errors in part (a) then led to incorrect responses in part (b). In general, most candidates were confident using slack, surplus and artificial variables. One recurrent error was to rearrange the constraint $x \geq 3y$ as $x - 3y \geq 0$ so that a third artificial variable was incorrectly introduced, in spite of the question stating, “using exactly two artificial variables”. Those candidates who did have two artificial variables usually went on to set up an equation for I using their a_1 and a_2, gaining the associated method mark. But the correct corresponding accuracy mark was frequently lost by candidates not explicitly stating the correct equations for both I and P, with variables on one side and constant on the other, before filling in the tableau. Most candidates managed to complete the tableau and achieve the method mark for two completely correct rows, though the associated accuracy mark was often lost due to prior errors. For a few candidates their only error was to write surplus variables, rather than artificial variables, in the basic variable column. The answer to part (c) was independent of the earlier parts of the question, providing an opportunity for those who had struggled previously to still make progress. Most candidates appeared well prepared in performing an iteration of the Simplex method, so many gained all five marks or lost just one mark due to a computational slip. There were some tables left blank, possibly due to timing issues. Only a handful of candidates chose the wrong pivot. Many candidates gained the mark in part (d)(i) for reading off the correct answer of £20 500 from the given table. For part (d)(ii) some candidates correctly calculated the time in minutes but lost the mark for failing to convert their answer to the requested hours. A pleasing number of candidates earned the final mark in (e), but a significant proportion gave spurious answers about the efficiency of the machines or other costs that might arise, rather than considering the direct context of the question.

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