Examiners' Report
Principal Examiner Feedback

Summer 2024

Pearson Edexcel GCE

In A Level Further Mathematics (9FM0)

Paper 3D Decision Mathematics 1

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Introduction

This paper was accessible to most candidates, although some questions proved to be challenging to a number of candidates, particularly where these involved either problem solving, or the use of technical language to show understanding of key topics. The questions differentiated well, while having marks available to E 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. Candidates must ensure that they use technical language correctly. This was a particular problem in question 4. Some poorly presented work was seen, with some writing difficult to decipher.

Question 1

This first question proved to be accessible to all candidates.

In part (a) many candidates answered this fluently recognising the relevance of the first two bins leading to $n < 41$ and $n \geqslant 40$. Those who did not get the mark mostly restricted their reasoning to the fact that bin 2 had the highest packing at 40.

In part (b) many candidates gained full marks confidently using the quick sort algorithm. Surprisingly, a few incorrectly chose 24 or 23 as their first pivot therefore losing all four marks. The quality of presentation was variable, ranging from those with new and previous pivots clearly distinguished, to confused, crossed out circled or underlined numbers. The most common error was carrying out the quick sort in ascending order. Candidates should be advised that this loses at least two marks, being marked as a misread, as has been indicated in previous reports. A subsequent reversed list does not recover those marks. Another error was to fail to pivot from the sub-list {8, 4}, presumably because it was already ordered. This lost two marks. It was rare to see just one pivot per pass, leading to the loss of three marks. Only a handful of candidates lost marks due to slips changing or losing a number.

In part (c) most candidates correctly completed this straightforward first fit decreasing bin pack, though some had 8 and/or 4 misplaced, losing the second mark.

Question 2

Parts (a), (b) and (c) were generally well approached and it was clear that many candidates understood how to apply Prim's algorithm. There were a small number of responses which chose to start the Prim's at a node other than D, but they were rare. Some candidates lost marks for not listing the arcs of the tree explicitly, sometimes giving a list of nodes instead, or even simply numbering the top of the matrix with the order of selection followed by giving the weight of the tree only. There were occasional errors in the order of selection, for example sometimes EH and EJ were incorrectly interchanged, and other errors arose from the apparent application of a nearest neighbour approach resulting in a route rather than a tree. In (b), most candidates were able to write down the weight of the MST correctly, even some who had made errors in Prims and the vast majority were able to draw the tree correctly in part (c).

In part (d) the majority of candidate realised they needed to double the weight of their minimum spanning tree to obtain the upper bound although some candidates were confused here with the method for the calculation of the lower bound and instead added 'two shortest lengths' or sometimes added just AD.

In part (e), the nearest neighbour algorithm was usually successfully applied with the most common error being the omission of returning to the starting vertex or sometimes due to missing a node en route.

In part (g), many candidates started again, rather than adapting the work already done. Those who used their minimum spanning tree from part (a) generally made fewer errors than those who recreated the work to produce an MST here. Nonetheless, most did arrive at the correct lower bound of 281.

In the comparison of upper and lower bounds in parts (f) and (h), it was clear that most candidates understood which would be the preferred option in either case and could clearly explain why. Some candidates were not quite specific enough though, giving explanations about the range being reduced rather than comparing the relevant values. The question was well answered overall, with most lost marks being due to slips rather than a misunderstanding of the content being assessed.

Question 3

In part (a) Dijsktra's algorithm was applied successfully by the majority of candidates. The usual errors were seen including missing working values, errors in the order of working values, occasional errors in order of labelling and occasional arithmetical errors. However, errors seemed to be perhaps less common that in recent series. A common error was a final value of 87 at H resulting in 93 at K and 96 at J. A small number of responses labelled their working values with the node from which it had come, which was acceptable. Sometimes candidates misunderstood what was being asked for the final mark in a) and gave the length of the shortest path rather than the shortest path itself. A common error here was the omission of C, resulting in an incorrect shortest path ABDGFHJ.

In part (b) most candidates could identify the five nodes which should be considered, but some were apparently at a loss for how to separate out into the cases of finishing at K or finishing at J in order to apply the route inspection algorithm. A small number of responses included G to have six odd nodes and attempted three pairings. For those candidates who did apply the correct approach, arithmetic errors were common, despite correct values having been obtained in part (a). It is apparent that many candidates are unaware of how to use the result of Dijkstra in the route inspection. Some failed to provide two full sets of pairings of the odd nodes and others did not give totals for each pairing. Candidates would benefit from more practice in presenting their solutions to this type of question to ensure that all steps are included. It was not uncommon, for example, to see the penultimate mark lost here due to the omission of either the repeated arcs being stated explicitly (often BK being stated rather than BD DG GF FH HK in full), or the lack of a conclusion of which node should be the finishing node. Credit was given to those candidates who had made an error in calculating the final values at J and K in part (a), but who used their values correctly.

Part (c) provided something of a challenge to many candidates and was a good discriminator. Responses that were seen offered elements of a correct approach and it was clear that there was understanding of the new combination of paths which were required to be travelled twice. However, only the strongest candidates realised the impact of the change in available arcs and the impact on the shortest path. It was common to simply reuse AJ = 94 without adjusting the length. The failure to either subtract the two arcs which had been removed or to increase the distance from A to J by two, due to the change in path following the arc deletion, resulted in common incorrect answers of 496, 507 and 509.

Question 4

This question required both accurate technical knowledge of the topic and good communication skills. Many candidates demonstrated one or the other, but not both.

In part (a) some candidates did give the simplest answer, that a graph cannot have an odd number of odd nodes. However, many candidates opted to sum the degrees and then struggled to convey why 21 was impossible. It was quite common to see true statements, which failed to answer the question, for example "the sum of the degrees must be even" but with no supporting working relating to the question. Euler's Handshaking Lemma was popular with candidates but not always quoted in a relevant fashion. A common misconception was that, as there were six nodes, no node could have a degree of more than five and some stated that the sum of the degrees could not exceed 12.

Part (b) was slightly better answered than part (a), although not all candidates knew that the nodes of a Eulerian graph are all even. Some of those who did so, correctly answered by simply stating that the node of order 1 is odd. Others wasted time considering which of the four expressions in *x* would be odd or even, depending on whether *x* was an odd or even number.

In part (c)(i) those candidates who knew that a tree with 6 nodes has five edges arrived at the equation $8x - 14 = 10$ with ease and solved this to get $x = 3$. This method was not often seen. Most candidates used inequalities, often getting in quite a muddle. Many did state either $4 - x > 0$ or $4 - x \geqslant 1$ but then wrote down all the other possible inequalities, getting some of them wrong such as $2x - 5 > 0$ leading to $x > 2/5$. Exhaustive testing of all positive integers up to 4 was an acceptable method for full marks and proved successful for a minority. Some optimistically just stated that $x = 3$, ruling themselves out of all three marks. For (ii) as this part of the question starts "hence" candidates were obliged to use the value of *x*, whether or not calculated legitimately. This part was often correct with candidates getting both marks for listing the six valencies, or those of at least two more odd nodes, and drawing the correct conclusion. Some were hampered by ignorance of what is meant by semi-Eulerian or used an incorrect term such as non-Eulerian.

In part (d) there were many correct graphs seen, with loops proving popular. However, the graphs of a minority were isomorphic and quite a few made no attempt to draw a graph.

Question 5

In part (a) many responses demonstrated that candidates understood how to use slack, surplus and artificial variables to construct their constraints successfully. However, there were errors seen in establishing the initial inequalities including a common error in translation of the multiplicative relationship between x and y resulting in $5x - y \leqslant 0$ rather than $x - 5y \leqslant 0$ Errors in the direction of one or more inequalities were also seen which, of course, impacted on the introduction of the dummy variables.

Setting up the new the objective function was the least successful part of the process, with $P = x + y - M\left(a_1 + a_2\right)$ seen frequently. Sign issues were almost usually the barrier here. In fact, many candidates omitted this step completely perhaps highlighting a lack of understanding for this aspect of the specification.

In most cases, candidates could transfer their constraints to the tableau although, again, some issues with signs were seen, as were errors in the basic variable labels.

Part (b)(i) was usually correct, and most candidates went on to substitute this into at least one inequality. However, substitution into all three constraint inequalities or the critical two was not always seen and the required processing to obtain $y \leqslant 30$ and $y \geqslant 30$ was sometimes not achieved. Insufficient reasoning therefore meant that the conclusion $y = 30$ was not always fully justified for the award of the final mark. A common incorrect answer was the use of $x = 5y$ to obtain $y = 26$.

Question 6

Overall, this question was very accessible with at least the first three marks in part (a) and the first mark in part (b) gained by most candidates.

In part (a) nearly all candidates that completed a network did put arrows on with only a minority losing the A1 CSO mark for this reason. A few candidates only gained 1 mark as they did not put arrows on any of their dummies. Extra dummies were more likely to be seen than missing dummies. A good proportion of candidates were able to start the network and correctly deal with up to J, and the first two dummies. There was then sometimes some confusion with how to deal with H, I, K and L. The most common error was to omit the dummy after F and G which resulted in L being shown as dependent on J in error. This cost these candidates the final two marks.

In part (b) nearly all candidates gained the first mark for the correct critical path, CEJK, with many also gaining the mark for the correct minimum completion time of 20 hours. A significant number of candidates calculated the correct float on Activity B of 2 hours, but It was rare to see a correct calculation for the total float on Activity G. Many candidates gave the float incorrectly as 0 (zero stated or 12 – 8 – 4 due to H starting immediately after G on the given scheduling diagram) or as 1 (as G depends on C which finishes at 7 but G starts at 8 on scheduling diagram).

In part (c) few candidates earned both marks by giving the complete detail required, expressing for example that:

Activity I could be done by Worker 2, starting at 12 hours (and finishing at 20) and

Activity H could then be done by Worker 3 from 15 hours (to 17) hours.

Many candidates had the right idea but did not actually write enough detail, for example by not mentioning specific timings. Several candidates thought that it was not possible to complete without a further worker or completing after 22 hours or splitting the activity between two workers.

Question 7

This question was attempted by most candidates, suggesting that they were able to complete the paper in time. Many candidates appeared unsure about parts (a) and (b) but were able to gain marks in the later parts.

Part (a) was frequently misunderstood with candidates indicating the next pivot, *z*, rather than the previous one, *x*. However, it was encouraging to see a minority of candidates rethinking their answer, crossing out *z* and restarting with *x*, perhaps after starting to attempt (b). It was quite common to see candidates state *x* but have difficulty expressing a correct reason, losing one mark.

Part (b) proved to be the most challenging part of the paper. It was evident that many candidates found it difficult, or impossible, to apply their knowledge to work backwards towards the initial tableau. Some recognised how to deduce two constraints, $4x + y - z \leqslant 40$ and/or $y + z \leqslant 26$, from the tableau rows involving one slack variable only, gaining just one mark for either. Examiners commented that a remarkable proportion of candidates failed to multiply the RHS of the first constraint, so they often saw "$\leqslant 10$". A pleasing number of candidates were successful though, using one of two possible methods, either reverse row operations or the algebraic approach eliminating s_2 from equations for the third constraint and the objective. Some used a hybrid of the two methods but got there in the end.

Part (c) was a routine application of the Simplex algorithm, with many candidates able to gain all four marks, or losing just one due to an arithmetic error. Most wrote the row operations correctly though some were not fully expressed and lost a mark, as they had actually used the correct operations. Rather than retaining fractions some candidates expressed numbers as terminating decimals, which meant they lost an accuracy mark.

In part (d) almost all candidates, who had completed tableau T, recognised the significance of negatives in the profit row and most went on to correctly state the values of the basic variables. The more able just stated the three values required, but those that also stated the value of P and/or the other non-basic variables were not penalised. Some incorrect language was seen here, with candidates just referring to the bottom row and this was penalised.

In part (e) a good proportion of candidates offered an explanation here. Most spotted the error and were able to describe it, some clearly and concisely, other in a rambling fashion.

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