Examiners' Report

Principal Examiner Feedback

Summer 2017

Pearson Edexcel GCE Mathematics

Decision Mathematics D2 (6690)

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Summer 2017
Publications Code 6690_01_1706_ER

Decision Mathematics 2 (6690) – Principal Examiner’s report

General introduction

The majority of students demonstrated sound knowledge of all topics and were able to produce well-presented solutions, making good use of the tables and diagrams printed in the answer book. Students should be reminded of the importance of displaying their method clearly. Decision Mathematics is a methods-based paper and spotting the correct answer, with no working, rarely gains any credit. In a minority of cases many marks are lost due to poor quality of handwriting, particularly when students misread their own written numbers and capital letters. Most students were well prepared for the exam and there were very few blank pages. In the final question, it was, however, evident that some students ran out of time, a few made no attempt at all and many more stopped mid-solution.

Question 1

It was surprising the number of students who seemed to find this first question rather demanding as it was meant to provide a relatively straight-forward start to the paper. Whilst it was clear that many students understood (from studying D1) the process of finding a minimum connector for a network it was disappointing how many students did not set out their application of Prim’s (or on rare occasions Kruskal’s) either correctly or accurately. As mentioned in the introduction this module is methods-based and so therefore in (a)(i) simply stating the MST only scored the first of the two marks available. However, it was reassuring that the vast majority of students understood that the initial upper bound for the MST method was to be found by doubling the weight of the corresponding MST.

Whilst part (a)(ii) was well answered by the majority of students, the most common error when applying the nearest neighbour algorithm was a failure to return to the starting vertex. There were also a significant number of students who found an upper bound by either doubling the length of the correct cycle or doubling the length of the path A – E – B – C – D – F. These students therefore give an incorrect answer of either 1118 or 924. All that was required in this part was a simple stating of the length of the Hamiltonian cycle found by applying the nearest neighbour method (which would have given an upper bound of 559).

Most students scored at least one mark in part (b) on the follow through from an earlier stated upper bound found in part (a). It was common, however, to lose the final mark in this part for either the use of a strict inequality for the upper limit, or because of inaccurate earlier working. It was rare but nonetheless worrying to see statements along the lines of $559 \le \text{length} \le 500$.

Question 2

Students attempted this question well with many scoring full marks. Nearly all students correctly applied the north-west corner method in part (a) to find the correct initial solution. A significant number of students did unnecessary calculations of shadow costs and improvement indices in part (b) to obtain an improved solution, despite being told which cell to use as the entering cell in this part. This often led to the candidate running out of space and needing additional paper – the space given for a question should be a guide as to how much working is needed.

Most students were able to attempt parts (b) and (c), with just a few marks being lost for errors such as leaving 0's in improved solutions, errors in the calculating of shadow costs and improvement indices (although nearly all students had the required 7 shadow costs and 6 improvement indices, so were able to score the method marks), or not explicitly stating the entering and exiting cells. It should be noted that the setting out of the shadow costs and improvement indices as shown in the published mark scheme (in which both sets of values are shown on the same table) is probably the clearest form of presentation; students who show many calculations at the side of the table can make it somewhat difficult for the examiner to find, or even follow, their corresponding method/working.

For part (d), many students calculated more improvement indices than were strictly needed in order to ascertain whether an optimal solution had been reached – as soon as a negative improvement index is reached it is perfectly acceptable to stop calculating more indices. Students should be aware that when they are requested to give a reason for whether a solution is optimal (or not) it is not sufficient to simply refer to "negatives" – it must be clear that it is the presence of a negative improvement index that infers whether or not a solution is optimal.

Question 3

Parts (a) and (b) on the whole were answered very well with only a minority of students incorrectly stating the row maximums and column minimums. Once again, students need to be made aware that this is a 'methods' paper; a number of students simply stated that the row maximin was 1 (or the corresponding play safe for A was 2) and the column minimax was 3 (or the corresponding play safe for B was 1) with no method or working to back up these claims. A number of students who did find the row maximin and column minimax did not indicate that these two values were not equal and so therefore there was no stable solution.

A costly error in part (c) was when the wrong dominance was stated although the vast majority did correctly delete row 3. The majority of students then went on to set up the three correct probability expressions (though some had errors when simplifying these expressions) and subsequently most went on to draw a graph with 3 lines; a few students attempted to just solve three pairs of simultaneous equations, scoring no marks.

It was noted by examiners that many graphs:

- were poorly drawn without rulers,
- went beyond the axes at $p < 0$ and $p > 1$,
- had uneven or missing scales on the vertical axes,
- were so cramped that it was difficult to identify the correct optimum point.

Most students attempted to solve the pair of equations for which they considered to be their optimal point. Those that solved the correct pair usually went on to list the correct options for player A although a number did not state that player A should never play their option 3. The value of the game to player B in part (d) was often stated correctly.

Question 4

The majority of students correctly defined the values taken by x_{ij} and the set of values that i and j could take. However, the majority of students did not define the objective function correctly as many decided to simply ignore x_{A3} and x_{D2} rather than making the coefficients of these two variables sufficiently large. A significant number of students made errors with their constraints, by either writing them as inequalities, ignoring x_{A3} and x_{D2}, using coefficients other than 1 (or having right hand sides not equal to 1) or with inconsistent notation e.g. using x_{11}.

Question 5

Part (a) was answered well by the majority of students with many correctly stating the objective function and the constraints as inequalities. The most common errors were:

- Stating the objective as either $P = -x - 2y - 5z$ or $P = x + 2y + 5z = 0$,
- stating the constraints as either $15x - 2y + 3z < 180, 15x - 2y + 3z \geq 180$, $15x - 2y + 3z + r = 180$ or even $15x - 2y + 3z + r \leq 180$.

In part (b), many students were able to correctly identify the pivot row and divide and replace *r* with *z* as a basic variable. Most students defined row operations in terms of the new row 1. There were of course a number of students who made errors in the subsequent row operation calculations. A significant number stopped after one iteration, in some cases stating that the solution was not optimal due to negative values in the profit row despite the fact that the question had asked for the problem to be solved. Of those who did proceed into the second iteration very few picked negative pivots and many were able to proceed correctly albeit with some errors in the pivot row calculations.

In part (c), it was clear that students either did not read the question carefully or assumed it was asking for students to write down the profit equation from the optimal tableau. Therefore many students did not state $P = 364$ but instead stated that $P + 40x + 0.6r + 3.2s = 364$. Furthermore, many did not state the final values of the slack variables and examiners noted that it was quite common to see $x = 40$ rather than $x = 0$ stated as one of the final values.

Question 6

Overall a small number of students failed to score any marks for this question and their responses clearly showed that they were considering the flow from A to F even though the question clearly stated that flow was from S to T.

In part (a), the vast majority of students correctly stated the initial flow. In part (b) while the majority of students still gave the correct answer a significant number gave responses of 64 or 140 showing a fundamental misunderstanding of cuts or 57, 81 or 105 showing they were considering flows rather than capacities.

In part (c), the majority of students annotated the diagram correctly, a small number transposing the values on arc FG. Another issue was students who may have labelled the diagram correctly but crossed these values out with their subsequent working. Students must be aware that only values which care legible can possibly be awarded the corresponding mark(s); anything requested in a question should be clearly visible, subsequent working should not overwrite this.

In part (d), while most students managed to find flow-augmenting routes most only found two or three of the four possible routes. A small number of students tried to consider reducing flows in some arcs rather than using the back flow as part of their route.

In part (e), most students went on to attempt the final flow diagram however a significant number of students did not gain full marks as they did not have a flow of 68. A number of errors were often present such as two numbers on some (or all) of the arcs (even though it has been mentioned in previous years (on a number of examiners' reports) that only a single number can be accepted on a flow diagram) and a significant number of students either left one arc blank or had an inconsistent flow pattern, most notably at nodes A or B.

Part (f) produced a variety of responses. Some students stated a value of a cut as equal to their flow but a minority of these did not show this cut on a diagram or state a set of arcs to indicate their cut. Many did not state the theorem that the maximum flow is equal to the minimum cut. It is advisable for students to draw the cut on the diagram showing their maximal flow pattern rather than stating the arcs that the cut passes through. Finally, students are reminded to refer to the original diagram containing the flow capacities when considering possible cuts, rather than their optimal solution.

Question 7

This type of dynamic programming question has not been asked for a number of years and as a result it caused some issues for a significant number of students. For the students who understood dynamic programming, there were a lot of marks to be gained. However, a significant proportion found this exceedingly challenging, particularly struggling with how to use the state/action/destination columns for this particular problem.

There were nonetheless a good number of perfect or near perfect responses where students were only, in a few cases, let down by arithmetical errors or a misreading of their own handwriting. There were also a number of students who appeared to start well but ran out of steam which may indicate a lack of time rather than lack of ability to complete the question. Some students filled in the table column by column and wrote down calculations in the value column but never got around to writing down the final values. This could be due to lack of time or perhaps due to ruling out some options by inspection. It is important that students show a complete method and values must be calculated not just given as a sum.

A number of students were clearly unsure how to begin and there were a number of students who made a number of separate attempts to restart the question. Many examiners saw a number of responses who abandoned dynamic programming altogether and used the columns for T-shirt, Rugby and Polo and then simply listed every possibility resulting in a total of five batches.

Of those that did appear to utilise a dynamic programming approach to solve the problem, it was surprising to see that many did not realise that the destination from T-shirts had to be 0 and that the state for Polo had to be 5. Many students switched the state and destination columns so that destination was effectively 'how many batches of shirts have I made' rather than 'how many batches do I have left to make'. Some students, despite confusing state/action destination were able to work through all the possibilities within each stage accurately and were able to obtain 9 marks out of a possible 13. Others still had long tables listing all possibilities from 0 to 5 for both Rugby and Polo and in some cases for T-shirts too. Most students who made some attempt were able to pick up at least one method mark in each stage.

There were some errors in writing down the profit at the end of (a) as some students failed to notice that profits were stated in 1000s and so gave an answer of £315.

The overwhelming majority who completed the table in (a) were able to correctly write down the two possible ways in which the batches could be allocated for maximum profit.

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