Examiners' Report
Principal Examiner Feedback

Summer 2023

Pearson Edexcel GCE
Further Mathematics (8FM0)
Paper 28 Decision Mathematics 2

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Summer 2023
Publications Code 8FM0_28_2306_ER*

Introduction

Most candidates 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. 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. In a minority of cases marks are lost due to poor quality of handwriting, particularly when candidates misread their own written numbers and capital letters. Most candidates were well prepared for the exam and there were very few blank pages. In the final question on recurrence relations, it was, however, evident that some candidates are still unfamiliar with this topic (not previously seen in either legacy modules 6689/01 or 6690/01) and several blank or low-scoring responses were seen by examiners.

Report on Individual Questions

Question 1

Many candidates scored very well on this question. Almost all could explain how to modify the table correctly in part (a) by saying that an additional dummy column of equal values was required to create a square array, and that a suitable large value needed to be entered into cells BQ and ES. When marks were lost in this first part it was usually down to being imprecise with language or detail (e.g. 'add a dummy **row** of equal values', or 'add equal values to cells BQ and ES').

In part (b), most candidates correctly carried out the corresponding row and column reductions. Accuracy errors at this stage were rare. Most candidates then recognised that three lines were needed to cover the zeros and were well versed in developing an improved solution twice to arrive at the optimal table. Many candidates though failed to clearly explain how they determined, at each stage, whether their solution was optimal. It is essential that candidates refer to the number of lines covering zeros and make it clear the number of such lines that are needed for optimality. However, candidates had no difficulty deducing the optimal allocation and the least total time to complete all four tasks in part (c).

Question 2

In (a) and (b) nearly all candidates correctly stated the initial flow from S to T as 72 and the value of the given cut (as 92).

Most candidates stated at least one correct flow-augmenting route in part (c) (together with its length) although some gave routes that totalled more than the maximum permissible increase (which was 5). Candidates are reminded that routes should be stated in terms of nodes starting with S and finishing with T.

Although many candidates correctly found the flow-augmenting routes required (to increase the flow by a maximum of 5 units) it was rare for candidates to draw a correct maximum flow pattern in part (d). Candidates are reminded that no arc should be left blank (a blank is not assumed to be 0) and that each arc should only have a single value written on it (and therefore they should not waste time showing the flow **and** the capacity on each arc).

Part (e) discriminated well with very few **proving** that the answer to (d) was optimal. To assist for future series please find below a way in which candidates can set out such a proof:

- It is best to state (and not just draw) a cut (that passes through saturated arcs that are directed from the source set to the sink set of nodes together with any arcs with zero flow that are directed from the sink set to source set) - so for this network as a list of arcs this was AD, BD, ED, EG, GJ and JT or as set of nodes $\{S, A, B, C, E, F, J\}, \{D, G, H, T\}$.
- State the capacity of this cut and hence what this implies about the minimum cut e.g., the value of this cut is 77 which implies that the minimum cut $\leqslant 77$
- State the value of the flow through the network after augmentation and what this implied about the maximum flow e.g., the current flow through the network is 77 which implies that the maximum flow is $\geqslant 77$
- Conclude the proof by referring to the maximum flow-minimum cut theorem e.g. the min. cut is $\leqslant 77$ and the max. flow is $\geqslant 77$ but by the maximum flow-minimum cut theorem the max. flow is equal to min. cut therefore the maximum flow is 77 and therefore the flow is indeed optimal.

Question 3

Part (a) was done very well, with most candidates finding correct row minimum and column maximum values, with very few errors. A small number of candidates failed to either correctly identify the row maximin and column minimax, or to verify that the game was stable with correct justification.

In part (b) the majority of candidates correctly wrote down the pay-off matrix for player *B*.

In part (c) most candidates set up three correct probability expressions (though some had errors when simplifying these expressions) and then most subsequently went on to draw a graph with 3 lines; a few candidates attempted to just solve pairs of simultaneous equations, scoring no marks. It was noted that some 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 candidates attempted to solve the pair of equations for which they considered to be their optimal point from their graph. Those that solved the correct pair usually went on to list the correct options for player *B* (that is, that they should play option X with probability $\frac{7}{10}$ and option Y with probability $\frac{3}{10}$) although a number did not state their answer in context. Those candidates who were successful in finding the correct value of *p* usually went on to correctly state the value of the reduced game to player *A* in part (d)(i).

Very few candidates made any real progress in the remaining parts of (d) indicating that candidates are still unfamiliar with how to solve the game for one player once the solution is known for the other.

Question 4

As expected, the final question on recurrence relations was the least well attempted on the paper and examiners noted that many candidates either left this question blank or made only minimal (unsuccessful) attempts. Some candidates did make a correct start though, writing down a correct complementary function plus a quadratic particular solution which they attempted to substitute into the recurrence relation, gaining the first two marks. Many attempts ended at this stage. However, a minority of candidates were well prepared for this topic and produced excellent solutions, particularly in part (a). The final mark was lost in part (a) for a few candidates when they expressed their solution as $u_{n+1} = ...$ (rather than implying $u_n = ...$). Relatively few candidates were able to complete part (b), but it was encouraging to see a good number setting their expression > 5000 and solving for *k*.

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