General Certificate of Education

Mathematics 6360

MD02 Decision 2

Report on the Examination

2010 examination – June series

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General

It was good to see that many candidates had prepared well for this examination. The new style question paper/ answer booklet seemed to improve the general neatness of presentation, but many candidates needed to use supplementary sheets and so extra blank pages are likely to be provided after some questions in future examinations. Topics such as Critical Path Analysis, the Hungarian Algorithm, the Simplex Method and Game Theory seemed to be fairly well understood. It was pleasing to see most candidates working with the table provided for the Dynamic Programming question. Unfortunately, a large number of candidates seemed unaware of what was meant by a minimax route. Those candidates who chose a network diagram approach usually lost more than half of the marks since they did not show the appropriate comparisons when obtaining values. Many candidates are still unfamiliar with the correct flow augmentation technique for a Network Flow question with upper and lower capacities.

Those preparing candidates for future examinations might find the following points helpful.

- In Game Theory, when a variable p is introduced, it should be clear what this represents and the graphs showing expected gains should indicate the expected values when $p = 0$ and $p = 1$ and the lines should only be drawn for $0 \le p \le 1$.

- When using the Simplex Method, it is advisable to indicate which entry has been selected as the pivot.

- In Dynamic Programming, candidates need to become familiar with a tabular stage and state idea, working backwards through the system, rather than always relying on a network approach. Those who do not use the table provided must show all equivalent working on their network or marks will be lost.

- When a network has upper and lower capacities the value of the cut is given by the sum of all the upper capacities on edges where the flow is away from the source minus the sum of all the lower capacities on edges where the flow is towards the source.

- When using flow augmentation, the labelling procedure requires that both the potential increase and decrease of flow are indicated on each edge. This is best done using forward and backward arrows (or a repeated edge one showing forward potential increase and the other showing backward decrease). The individual routes augmenting the flow and the values of the extra flows should be recorded in the table provided.

Question 1

This proved to be a very high scoring opening question for most candidates.

Part (a) The earliest start times were usually correct, but the latest finish times for some activities were sometimes calculated incorrectly.

Part (b) Most candidates found at least one correct critical path, but sometimes spoiled their answers by adding a third path that was not a critical path. Some candidates listed all the critical activities instead of giving the critical paths and scored no marks for this.

Part (c) Most cascade diagrams indicated the critical activities correctly. Quite a lot of candidates failed to show the correct slack for activities C, D, G , I or J. Others had slack overlapping another activity and this was not acceptable.

Part (d) The last part of the question was answered well by most candidates, although some failed to mention the new earliest starting **day** for either K or L.

Question 2

Part (a) The printed answer helped most candidates to be successful in the initial row and column reductions, although a few failed to show that k was equal to 6.

Part (b) The Hungarian algorithm seemed to be understood much better in this fairly straightforward question that required just a single augmentation.

Part (c) Some candidates only gave one way of allocating students to games, but it was pleasing to see many correct solutions showing both allocations.

Part (d) Most candidates found the correct minimum total of penalty points, provided they had at least one correct matching.

Question 3

Part (a) Most candidates formed the correct initial tableau, although some failed to include any slack variables and scored no marks. Some misunderstood the request in this part of the question and wrote down three equations introducing the slack variables s and t . Full credit was given if they produced the initial Simplex tableau as their first step in part (b).

Part (b)(i)Those who chose the incorrect pivot could make little progress. However, most candidates chose the correct pivot and answered this part of the question well, apart from a few who made numerical slips.

Part (b)(ii) Many more candidates than on a previous occasion, when a similar question was set, realised that the entry in the top row had to be negative; they formed and solved the correct inequality writing $6k - 3 < 0$ and hence that $k < 0.5$.

Part (c) Those with the correct tableaux, or who made an arithmetic slip in one of their rows, were able to score full marks for finding the values of P and the variables x, y and z. Some failed to state that $y = 0$ and others omitted the value of z. Part of the interpretation of the final tableau was a statement that the optimum had now been reached and many candidates failed to score the mark for this.

Question 4

Part (a)(i) Despite the standard nature of this question, it was surprising to see several candidates who were unaware of how to find the optimal mixed strategy. A good sketch showing the feasible region was expected, with the highest point of the feasible region being selected in order to find the probability of playing the various rows. Many gave no reason for introducing a probability p and failed to describe the actual mixed strategy when the value of p had been found.

Part (a)(ii) The printed answer helped many candidates to check their previous results when finding the value of the game. Quite a few, who had previously found that $p = \frac{5}{13}$, wrote that "the value of the game was $1 - p = \frac{7}{13}$ "

Part (b) A large number of candidates made no attempt at this part of the question. Others who only partly remembered the technique wrote down expressions such as $7p + 3(1 - p) - 5(1 - p - q)$ and scored no marks. A few reasoned correctly using the result from part (a) that C_1 should never be played and reduced their matrix to a simple 2 by 2 game and then solved a pair of simple equations or a single equation such as $3p - 5(1-p) = \frac{7}{13}$ which scored full marks, provided things had been clearly explained. Although it is not in the specification, one or two candidates used a Linear Programming Simplex approach with little explanation and no solution seen was deemed worthy of any marks.

Question 5

Quite a large number of candidates seemed unfamiliar with how to solve a problem requiring the minimax route. In fact it was very common to see tables with values being added together so as to find a route of maximum or minimum length.

Part (a) In the explanation, too many candidates simply repeated the wording below the diagram in the question. It was expected that candidates would find the maximum single day's journey for each of the two routes and then to reason that 12 was less than 13 thus making the route *PQSV* better than the route *PQTV*.

Part (b) Many candidates who used the table provided for this question scored full marks. Some made slips in their calculations but they were still able to show a clear method of solution. To score full marks, the word "maximum", or equivalent such as "$12 > 11$", needed to appear in the calculations, rather than simply writing down pairs of values being compared. A small number of candidates used a network diagram, but in order to score full marks they needed to show the values and calculations equivalent to those in the table; in most cases these calculations were not seen and so marks were lost.

The minimax route was found by finding appropriate minimum values for each state at the various stages and full marks were only awarded for the minimax route if the corresponding values in the table were correct, condoning the odd slip.

Question 6

Part (a) Most candidates seemed unaware of how to calculate the value of the cut correctly because of the upper and lower capacities. Some subtracted 9 instead of 5 from the sum of the other upper capacities; others merely added a set of positive numbers.

Part (b) In contrast, almost everyone scored full marks for finding the value of each of the missing flows along the given edges.

Part (c)(i) Some candidates still seemed unaware of how to represent the potential increases and decreases **from the initial feasible flow**. It requires forward and backward arrows or a duplicate edge; one showing potential forward flow, the other the potential backward flow. The initial flow values are best written in black ink close to the arrows so that any adjustments can be shown in pencil so as not to obliterate the initial flow figures.

Part (c)(ii) A table was provided so that a flow of 2 along *SABT*, for example, could be listed in the table. The potential forward and backward flows along *SA, AB* and *BT* could then be adjusted on the diagram by lightly crossing out the original flows along each edge and indicating the new values. If candidates obliterate their values of the potential increases and decreases from part(i) then they risk losing marks for that part. The majority of candidates found only 2 augmenting paths and were not able to find the correct maximum flow. Those who were not using the labelling procedure correctly sometimes obtained a flow that was impossible; for instance a maximum flow of 29 was seen quite often. It should be noted that candidates are not expected to do flow augmentation with negative flows.

Part (c)(iii) Some credit was given for transferring values from Figure 4 to Figure 5 even if the maximum flow had not been achieved; but full marks could only be scored for a correct flow of 28 through the network.

Part (d) Very few candidates realised the need to consider their saturated arcs in order to obtain the correct cut. Many wrongly considered their flow on Figure 5, where obviously every cut has a value of 28, and consequently wrote down cuts such as the one through BT, DT and ET as their final answer. That is why the question suggested that candidates “may wish to show the cut on the network above” since that network contained all upper and lower capacities.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the **Results statistics** page of the AQA Website.