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General Certificate of Education

Mathematics 6360

MD02 Decision 2

Report on the Examination

2009 examination - June series

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Registered address: AQA, Devas Street, Manchester M15 6EX *Dr Michael Cresswell Director General.*

General

It was good to see many candidates had been well prepared for this examination. Those who took care to explain their methods, clearly showing all the necessary steps in their solutions were rewarded.

Once again, topics such as Critical Path Analysis, the Simplex Method and Game Theory seemed to be fairly well understood. Candidates who used the insert for the Dynamic Programming question produced some very good solutions.

Unfortunately, those candidates who were only aware of a network diagram approach usually lost more than half of the marks since they did not show the appropriate values at each stage. 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 $0 \le p \le 1$.
- The Hungarian algorithm is used to find a minimum value matching. Candidates need to understand what the new entries represent when each element has been subtracted from a fixed value.
- Many candidates do not understand the adjustment process of the Hungarian algorithm, after reducing rows and columns. The lines required to cover the zeros should be drawn and the minimum value, m, of the uncovered numbers should be stated before the matrix is adjusted by adding m to the entries covered by two lines and subtracting m from the uncovered entries.
- When using the Simplex Method, it is necessary to indicate which entry has been selected as the pivot when asked to do so. When using row operations, the pivotal row should remain unchanged.
- 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 insert 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 good opening question for all candidates. The earliest start times were usually correct but the latest finish times for *D, B* and *A* were sometimes calculated incorrectly. Most candidates found the correct critical path, but quite a few forgot to state the minimum completion time. Those with a correct activity diagram were usually able to find the new start times for *H* and *I* after the delay. A few thought that the minimum delay was 1 day and others stated that the delay was 24 days, when in fact this was the new completion time.

Question 2

In part (a), few candidates mentioned that, ***for each outcome***, one player's gain plus the other player's gain is zero in a zero-sum game.

In part (b), most responses indicated that C_1 was Colin's play-safe strategy. However, the accompanying explanations were often poor with many producing the standard table indicating that there was no stable solution when this was not required. Better candidates gave the column maxima, namely 2, 5 and 4, together with a comment about 2 being the minimum of these column maxima.

In part (c), the idea that R_3 was dominated by R_1 was well understood, but some candidates spoiled their answer by suggesting that strategy R_3 was worse than both R_1 and R_2.

Despite the standard nature of this question, it was surprising to see many candidates unaware of how to find the optimal mixed strategy in part (d). 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 nor explained what the actual mixed strategy was when the value of p had been found. Many candidates calculated the value of the game, which was not required

Question 3

The explanations in part (a) were often poor, with many simply repeating the wording of the question. Quite clearly many thought the number 17 was relevant when of course it is not. The point missed by many was that the individual entries after subtraction from 17 were now a measure of the criteria **not** met which needed to be minimised in order to make the best allocation of lecturers to courses.

The printed answer in part (b) helped most candidates to be successful in the initial row and column reductions.

Part (c) gave candidates the opportunity to show that they really understood the Hungarian algorithm. A few ignored the request to cover the zeros with specific lines and did not score full marks even though they performed an appropriate adjustment. Many weaker candidates scored just a single mark for drawing appropriate lines.

In part (d), some only gave one way of allocating lecturers to courses, but it was pleasing to see many correct solutions showing both allocations.

In part (e), most candidates found the correct maximum total score provided they had at least one correct matching.

Question 4

Several candidates had the wrong inequality signs in part (a) and others included s and t in their answers.

Many candidates failed to indicate the pivot in part (b)(i) and lost a mark; many having found the quotients 7/1 and 10/2 gave the pivot as 5; others simply drew an arrow pointing horizontally towards the 10, which was insufficient. Those who chose the incorrect pivot could make little progress. However, apart from a few who made numerical slips, most candidates answered this part of the question well. In part (b)(ii), most were unable to see why $8 - k < 0$ and hence that $k > 8$.

In 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.

Question 5

In part (a), most candidates who used the insert provided scored full marks. Some made careless errors in their arithmetic, but they were still able to show a clear method of solution. A small number of candidates insisted on using a network diagram, but in order to score full marks they needed to show the equivalent values as in the table; invariably this was not the case and so lost marks.

In part (b), most candidates obtained the correct sequence of actions, but a few forgot to calculate the maximum profit.

Question 6

In part (a), most candidates seemed unaware of how to calculate the value of the cut correctly. Many subtracted 17 instead of 10 from the sum of the other upper capacities.

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

Some candidates still seemed unaware, in part (c)(i), 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 best be shown in pencil so as not to obliterate the initial flow figures. In part (c)(ii), a table was provided so that a flow of 1 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 (c)(i), then they risk losing marks for that part. The majority of candidates found only 3 augmenting paths and were not able to find the correct maximum flow.

In part (d), those who used flow augmentation correctly usually had no trouble in completing the diagram to show a maximum flow of 44 litres per second.

In part (e), very few candidates realised the need to consider their saturated arcs in order to obtain a minimum cut. Many wrongly considered their flow on Figure 5, where obviously every cut has a value of 44, and consequently wrote down cuts such as BT, ET and GT as their final answer.

Mark Ranges and Award of Grades

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