Version : 1.0 0608

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Report on the Examination

2008 examination - June series

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Set and published by the Assessment and Qualifications Alliance.

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General

It was good to see many candidates who had been well prepared for this examination and who took care to explain their methods clearly, showing all the necessary steps in their solutions. Once again, topics such as critical path analysis, linear programming using the Simplex method, and game theory seemed to be well understood. It was encouraging to see many more candidates using the correct flow augmentation technique for the network flow question with upper and lower capacities.

This was the first time that production planning using dynamic programming had been tested. Candidates who used the insert and took time to calculate the different values produced some very good solutions. Unfortunately, those candidates who were only aware of a network diagram approach found the problem very difficult and often made little progress.

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

- Cascade charts need to indicate the float, usually as a dotted line, when activities are non-critical.
- The Hungarian algorithm is used to find a minimum value matching. Candidates need to understand why subtracting each element from a fixed value allows the Hungarian algorithm to be used to maximise.
- In game theory, the graphs showing expected gains should indicate the expected values when $p = 0$ and $p = 1$, and the lines should only be drawn for $0 \leqslant p \leqslant 1$.
- When using the Simplex method, it is necessary to show which calculations have been performed if asked to explain why a certain value should be 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 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 and latest finish times were usually correct. Some candidates only gave one critical path instead of two. Quite a large number thought that $ADGJK$ was also a critical path and lost a mark. Despite showing a value of 22 on their insert, several candidates forgot to state the minimum time for completion. The cascade diagram caused few problems. Some candidates used blocks with critical activities linked together and other activities drawn in blocks above; others used a sequence of horizontal lines with the vertical axis labelled from A to K. The main reason for losing marks in part (c) was the ignoring of the slack or float. The explanation in part (c) was

not always adequate: it was necessary to explain that F needed to start after 12 days at the earliest, with I and K being delayed by one day, and hence that the new minimum completion time was 23 days.

Question 2

In part (a), the explanations were often poor, with many candidates simply repeating the wording of the question. Quite clearly, many thought the number 20 was relevant, when of course it was not. The point missed by many was that the individual entries after the subtraction from 20 were now a measure of the number of points **not** scored, which needed to be minimised in order to make the best allocation of people to games.

In previous years, surprisingly many candidates made errors in the initial row and column reductions, but the printed answer in part (b) helped most candidates to be successful at this stage.

Part (c) gave candidates the opportunity to show that they really understood the Hungarian algorithm. Some ignored the request to cover the zeros with specific lines and did not score full marks, even though they performed an appropriate adjustment.

In part (d), some only gave one or two ways of allocating people to the computer games, but it was pleasing to see many correct solutions showing all three allocations.

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

Question 3

Despite the standard nature of part (a)(i), it was surprising to see many candidates 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 candidates gave no reason for introducing a probability p nor explained what the actual mixed strategy was when the value of p had been found.

In part (a)(ii), it was quite surprising to see a number of candidates substituting $p = 0.5$ into their third (unused) expression and consequently obtaining the wrong value of the game, even though the answer was printed in the question.

In part (b)(i), almost everyone obtained the correct answer of $1 - p - q$. Part (b)(ii) was more discriminating, and it was obvious that some were totally unfamiliar with the technique needed. Many did not see the need to use the value of the game, and others made errors in their algebra. Nevertheless, there were quite a few completely correct solutions to this part of the question.

Question 4

In part (a)(i), candidates made vague statements such as “it has the smallest value when divided into the value” when explaining why 4 was the pivot. It was expected that at least three complete divisions would be performed with a comment about the smallest positive quotient being selected and hence 4 being the pivot.

In part (a)(ii), 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), Most were able to explain why the optimum had been reached.

In part (c), those with the correct tableau, or those who made an arithmetic slip in one of their rows, were able to score full marks for finding the value of P and the other variables.

In part (d), many failed to give the value of $v = 4$, and a large number of candidates seemed unaware of how the values of the slack variables related to the original inequalities.

Question 5

Previous reports had flagged up the fact that candidates using the table provided on the insert tended to be far more successful than those who attempted a network approach. Nevertheless, it seems that some candidates were only prepared for solving dynamic programming using a network approach.

It would seem that some candidates were affected by the unfamiliar nature of this question and made little or no attempt at it. In part (a), the word "overhead" seemed to confuse some candidates and, on reflection, it might have been better if a different phrase could have been used. Rather than realising that £300 was the cost involved when 3 cabinets were made, some candidates multiplied £300 by 3 before adding the cost of storing two cabinets. If they had looked at the first row of the insert, they would have seen that when two cabinets were being made and none were in stock the cost was £300 + £0. This might have prevented the error, and perhaps candidates might have gone back and corrected their earlier misunderstanding.

In part (b), those who found the next two entries in the table were usually successful in completing all the values in the table correctly. Once the table was complete, it was an easy task to work backwards through the table using dynamic programming to decide how many cabinets needed to be made each month.

The first two marks in part (c) were earned by almost everyone who realised that 13 cabinets were being made altogether. They calculated the profit to be £14 100. Very few earned the third mark for realising that they had to subtract the minimum value from their table, thus giving a total profit of £12 850.

Question 6

In part (a), about half the candidates seemed unaware of how to calculate the value of the cut correctly. In part (b), by contrast, almost everyone scored full marks for finding the value of the missing flows along the given edges.

In part (c)(i), some candidates still seemed unaware of how to represent the potential increases and decreases **from the initial feasible flow**. It required 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, with any adjustments then shown in pencil so as not to obliterate the initial flow figures.

A table was provided in part (c)(ii) so that a flow of 3 along SPUT, for example, could be listed in the table. The potential forward and backward flows along SP, PU and UT could then be adjusted on the diagram by lightly crossing out the original flows along each edge and indicating the new values. There are many correct solutions to this part, and teachers might find it informative to consider different possibilities with their future students in order to illustrate that, whatever solution they obtain, the maximum flow is still the same.

In part (c)(iii), those who used flow augmentation correctly usually had no trouble in completing the diagram to show a maximum flow of 39 litres per second.

Mark Ranges and Award of Grades

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