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Mathematics 6360

MD02 Decision 2

Report on the Examination

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General

It was good to see a number of candidates had been well prepared for this examination and took care to explain their methods clearly, showing all the necessary steps in their solutions. Others, however, took a minimalist approach and often lost marks because of poor or inadequate attention to detail. Once again, topics such as Critical Path Analysis, Linear Programming using the Simplex Method and Game Theory seemed to be well understood. Network Flows with upper and lower capacities proved difficult for many candidates who did not understand the flow augmentation technique. Dynamic programming is another area where far too many candidates seem to be only aware of a network diagram approach.

- The adjustment process of the Hungarian algorithm, after reducing rows and columns, was not always evident. 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.

- 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 $0 \le p \le 1$.

- In dynamic programming, candidates need to become familiar with a tabular stage and state presentation, working backwards through the system, rather than always relying on a network approach.

- When using flow augmentation, the labelling procedure requires that both the potential increase and decrease of flow be 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

The precedence table was usually correct and the earliest start times and latest finish times were found correctly by most candidates. Quite a few gave the latest finish time for activity *F* as 10 rather than 11, and consequently had values of 5 and 2 at *C* and *A* respectively; this was treated as a single error. Those with the correct values on the activity diagram were able to find the correct critical path and were able to conclude that activity *E* had the greatest float time. This proved to be a very good opening question for all candidates.

Question 2

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

Part (b) gave candidates the opportunity to show that they really understood the Hungarian algorithm. Many realised that 2 was the greatest uncovered value and subtracted 2 from each uncovered entry but neglected to add 2 to the entries which had two lines passing through them. A number of arithmetic errors occurred, particularly in the second stage of adjustment.

In part (c), some candidates only gave one way of allocating managers to centres, but there were many correct answers here, even when part (b) had not been correct.

Most candidates found the correct answer of £35 in part (d), but some gave two values for the minimum cost and others made careless arithmetic errors.

Question 3

Part (a)(i) proved to be the most testing part of this question, with very few candidates giving a good reason why Rose should choose R_1 as the play-safe strategy. The minimum value in each row had to be calculated and then the maximum of these minima needed to be shown to equal –1. In part (a)(ii), the better solutions gave a table with the column maxima 5, 2 and 5 clearly stated and with the minimum of these values indicated. A statement that the minimax value, 2, was not equal to the maximin value, –1, from part (a)(i) was then required to show that the game has no stable solution.

In part (b), most candidates realised that R_1 dominates R_3 and showed that corresponding entries of R_1 were greater than those of R_3.

The expressions for the expected gains in part (c) were usually correct, although some made algebraic slips when trying to simplify their expressions. There was a casual approach by many when drawing the graphs. Lines were often too short or too long and many made no attempt to indicate values on the vertical axis. Candidates do not appear to know what the three lines on the graph represent. Some seemed to guess which two expressions to equate when finding the optimal mixed strategy for Rose, instead of considering the highest point in the feasible region. It was necessary to make a statement indicating that Rose plays R_1 for $\frac{2}{3}$ of the time and R_2 for $\frac{1}{3}$ of the time in order to score full marks in part (c)(iii). It was quite surprising to see a number of candidates substituting $p = \frac{2}{3}$ into their third (unused) expression and consequently obtaining the wrong value of the game.

Question 4

In part (a), some candidates did not have the correct inequality sign and others included the slack variables in either an equation or an inequality.

A small number of candidates seemed unprepared for the Simplex method in part (b). However, apart from a few who made numerical slips, most candidates answered this part of the question well. Most were able to explain why the optimum had not yet been reached.

In part (c)(i), quite a few candidates failed to identify the correct pivot at the second iteration stage and scored no marks for their row operations. It is good practice to state the value of the pivot at each iteration in order to convince the examiner that the correct method is being used. Those candidates who used unorthodox tableaux usually fared worst since they often made more errors in their calculations. When asked to interpret the final tableau in part (c)(iii), most candidates failed to say that *P* had reached a maximum or optimum value; others neglected to give the value of each of the slack variables. Consequently very few indeed scored full marks in this part of the question.

Question 5

This question was answered by candidates rather poorly on the whole. Some candidates did not try dynamic programming at all and scored no marks for a complete evaluation. Many candidates seemed to have only been prepared to work forwards through a network. Some credit was given for this approach on this occasion, but that may not always be the case, particularly when the word **backwards** was printed in bold type. Those who were familiar with a stage and state approach found the table remarkably helpful.

There was, however, a reluctance to use the insert and many candidates decided to draw a network or their own table of values, and sometimes produced perfectly good solutions by working backwards from month 3. Others tried to use the table, but started with the numbers for month 1 and worked upwards through the table; usually with this approach the values that appeared in the table were nonsense and scored no marks.

Question 6

In part (a), very few candidates seemed prepared for a question with lower capacities as well as upper capacities, and consequently the correct value of the cut was rarely seen.

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

In part (c)(i), many candidates seemed unaware of how to represent the potential increases and decreases from the initial flow. It requires forward and backward arrows or a duplicate edge: one showing the potential forward flow, the other the potential backward flow. In part (c)(ii), flow augmentation was not widely understood. A table was provided so that a flow of 2 along *SMNT* could be listed in the table. The potential forward and backward flows along *SM*, *MN* and *NT* could then be adjusted on the diagram by lightly crossing out the original flows along each edge and indicating the new values. Candidates who used flow augmentation correctly usually had no trouble in completing the diagram in part (c)(iii) to show a maximum flow of 24.

Mark Ranges and Award of Grades

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