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Mathematics MD02

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Decision 2

Report on the Examination

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General

Once again, the general performance of candidates was very pleasing and on the whole solutions were presented clearly and legibly; this is essential when examiners have to check each step of the various algorithms. Basic algorithms appeared to be well understood by most candidates; however, when candidates were asked to explain or to show why a particular result was true, the responses were often quite poor.

Regarding the Hungarian algorithm, it is not acceptable to use the table provided in the question paper simply crossing out various numbers and replacing with new values; examiners cannot be expected to give credit for such unclear procedures, where it is almost impossible to check that the algorithm has been applied correctly.

It was again very encouraging to see the improved performance by candidates in the dynamic programming question and it is clear that the partially completed table helped. There has been a tremendous improvement since candidates have abandoned methods based on tracing paths on a network and marks have increased accordingly.

The labelling procedure in network flows is also becoming more familiar and most candidates are now using the correct method to indicate potential increases and decreases on their network diagrams; backward arrows to show existing flows and forward arrows to indicate potential flows. Those candidates who use single arrows with amended values, or values with no arrows at all, score no marks.

Question 1

(a) Almost every candidate calculated the earliest start times and latest finish times correctly.

(b) At least one critical path was found correctly by almost everyone and most candidates found the two critical paths. A surprising number neglected to state the minimum time for completion; it was not enough to simply have this value in the final box on the diagram.

(c) Those candidates who made errors in their earliest start times and latest finish times were given credit for identifying their activity with the greatest float time and the majority seemed aware of how to calculate its value.

(d) Greater care should be taken when drawing diagrams of this type, preferably using a ruler. The most common error in the cascade diagram was the omission of slack for the non-critical activities. Despite the bold printing of the word **late**, many showed *B, E, G* and *J* starting as early as possible. Some tried to fit activity *G* in two sections, with one of the two blocks slotted between activities *I* and *J*, so the diagram resembled a histogram.

Question 2

Most candidates were able to apply the Hungarian algorithm correctly. There are still, however, a few candidates who insist on crossing out values in a single table rather than producing a new matrix for each stage of the algorithm. This should be discouraged since it makes the examiner's task almost impossible and candidates are unlikely to score many marks for this approach. Despite comments in previous reports, this message does not seem to have been relayed to teachers and their candidates. This problem required only one augmentation but there were **three** possible ways of allocating the five people to the five puzzles. Despite obtaining more than one matching, some candidates thought these had different completion times.

Question 3

(a) Explanations rarely scored full marks. In order to show that the game has a stable solution, it was expected that the maximum values in the columns would be indicated before finding the minimum value of these maxima. The maximum of the row minima also needed to be found. Some statement should then have been made indicating that these two values were equal and hence that the game has a stable solution. Quite a few candidates felt that all they needed to do was to draw arrows pointing to –3 when an explicit statement was required regarding the play-safe strategies for each player.

(b)(i) Most candidates were able to find the optimal mixed strategy for Rohan. Very few made a statement such as "Let Rohan play R_1 with probability p"; usually the letter p was introduced with no explanation. Some lost marks for not drawing accurate graphs of expected values for $0 \leq p \leq 1$. Although it is acceptable to use the horizontal lines printed in the answer book, at least one of these vertical lines should have a clear scale so that the accuracy of the process of finding the highest point in the region can be checked by the examiner. Those finding the correct optimal strategy were usually able to find the correct value of the game, but for full marks it was necessary to make a statement regarding the frequencies of playing the two strategies.

(b)(ii) A large number of candidates were not prepared for this part of the question. Despite the wording in the question, very few made the correct start using the **three** probabilities p, q and $1 – p – q$ in order to obtain a pair of simultaneous equations in p and q. Those who made a correct start usually completed and found the optimal mixed strategy for Carla; some candidates, however, did obtain values for p and q which were either negative or more than 1.

Question 4

(a) Some candidates wrote down incorrect inequalities and quite a large number wrote down equations involving the slack variables s, t and u.

(b)(i) The pivot from the bottom row was usually identified correctly but careless arithmetic prevented many from scoring full marks.

(b)(ii) Although many wrote down that $12 – k$ was negative, it was common to see errors in handling the inequality, with quite a number not concluding that $k > 12$.

(c)(i) A large number of candidates selected –8 as their new pivot, and scored no further marks in the question. Those candidates who found the next pivot correctly often made some arithmetical slips and so only the very best candidates completed the second iteration correctly.

(c)(ii) Part of the interpretation was to say that the maximum value of P had now been reached, but very few candidates realised this. The values of P, x, y and z needed to be stated but some neglected to state that $x = 0$, even when their previous tableau was correct. Quite a number of candidates failed to find the correct values of the slack variables.

Question 5

(a) Many candidates failed to obtain the correct value of the cut, usually as a result of subtracting 6 instead of adding 0.

(b) Again, few had trouble finding the maximum flows along the given edges.

(c)(i) It was good to see candidates trying to set out their solution in a logical manner and once again the diagram and table clearly helped. Only a few candidates failed to show potential forward **and** backward flows on their network. Candidates are advised to use the table to show what new flows have been introduced and to modify both the forward and backward flows in their network. The previous values should be clear to the examiner when such modification is made. Marks are awarded for the initial flow and it is very difficult to credit candidates for their original values if they have been obliterated during augmentation. This was a good discriminator and tested that candidates understood the labelling procedure. Only the best candidates realised the need to augment a flow in the direction from *D* to *B;* not many obtained a flow greater than 80 and very few achieved the correct flow of 85 with a fully augmented correct diagram.

(d) Most candidates realised that they needed to reduce their total flow by 4 because of the vertex restriction, but only the best candidates obtained the correct maximum number that could move through the network during the fire drill.

Question 6

Good use was made of the table and, apart from a few arithmetic slips, a large number of candidates scored full marks for completing the table of values, thus indicating a good understanding of dynamic programming in this context. It was pleasing to see how many candidates completed the question despite it requiring a lot of calculations before deciding the correct schedule for building the sheds. A few disregarded the table, preferring to use a network, and if they had all the necessary calculations and values they were able to score full marks.

Mark Ranges and Award of Grades

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