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Examiners' Report
Principal Examiner Feedback

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In Decision Maths (WDM01)

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General Introduction

This paper proved accessible to the students. The questions differentiated well, with most giving rise to a good spread of marks. All questions contained marks available to the E grade students and there also seemed to be sufficient material to challenge the A grade students. Students are reminded that they should not use methods of presentation that depend on colour, but are advised to complete diagrams in (dark) pencil. Students are also reminded that this is a ‘methods’ paper. They need to make their method clear, ‘spotting’ the correct answer, with no working, rarely gains any credit. Some students are using methods of presentation that are too time-consuming and are therefore reminded that the space provided in the answer book, and the marks allotted to each part, should assist students in determining the amount of working they need to show. Some very poorly presented work was seen and some of the writing, particularly numbers, was very difficult to decipher. Students should ensure that they use technical terms correctly. This was a particular problem in questions 1(a), 2(c) and 7(c).

Report on Individual Questions

Question 1

Part (a) had a variety of responses – the best responses contained the key ideas that a bipartite graph consists of two sets of vertices X and Y in which edges only join vertices in X to vertices in Y and do not join vertices within a set. Students need to use the correct technical language such as ‘nodes’ or ‘vertices’, rather than points, dots, people, data etc. Some students were thrown by the diagram and had explanations referring to columns of nodes. A lot of students who correctly wrote ‘two sets of vertices’ went on to say that arcs cannot connect vertices in the same set but did not explicitly state that arcs connect vertices from one set to the other.

Part (b) was well attempted and most students were able to write down an alternating path from D to 3. It is important that examiners can clearly identify the alternating path so it should be listed (rather than drawn) separately, rather than left as part of a ‘decision tree’ of potential paths. A number of students are still not making the change status step clear. This can be done either by writing ‘change status’ or, more popularly, by relisting the path with the alternating connective symbols swapped over, this latter approach has the additional advantage of making the path very clear to examiners. A significant number of students did not state the complete matching in (b). If students are going to display the complete matching on a diagram then it must be made clear that only a diagram with the exact number of required arcs going from one set to the other set will be accepted.

Question 2

Full marks were fairly common in part (a) although there were a number of responses which got one or two of the values incorrect, in particular y or z tended to be the ones that were most often incorrect.

In part (b), the Gantt chart was usually well attempted and errors usually arose as a result of errors in (a) or sometimes due to the omission of an activity (often N), there were also occasionally issues with the lengths of activities or floats, for example, at the ends of activities D, F and/or G. As a result the vast majority of students were able to gain the method mark and mostly the first accuracy mark too. There were very few blank attempts or scheduling responses. Occasionally a scheduling diagram was seen after a cascade chart, possibly to be used in the next part of the question despite specifically not being required. There were some cascade diagrams that were unclear and, in such cases, it was difficult for examiners to tell exactly where some activities ended and therefore were floats began. It is important to stress to students the importance of clear diagrams.

In part (c), most students were able to conclude that the minimum number of workers is 4, and were usually able to identify which activities must be occurring simultaneously. It was challenging though for some students to identify a correct time at which the four activities must be taking place. It should be noted that a reference to time which included time 14 or time 16 was not valid and a significant number of students lost a mark as their stated time intervals were ambiguous, for example, 14 - 16. Some students did not provide responses to part (c) which considered time and activities but rather carried out lower bound calculations. There were a small number of responses which provide the correct information regarding time and activities but did not provide the required number of workers.

Question 3
Part (a) was usually very well done with most students applying Dijkstra's algorithm correctly. The boxes at each node in (a) were usually completed correctly. When errors were made it was either an order of labelling error (some students repeated the same labelling at two different nodes) or working values were either missing, not in the correct order or simply incorrect (usually these errors occurred at nodes D, G, H and/or J). The path was usually given correctly and most students realised that whatever their final value was at J, this was therefore the value that they should give for the length of their path. As noted in previous reports because the working values are so important in judging the students' proficiency at applying the algorithm it would be wise to avoid methods of presentation that require values to be crossed out.

The vast majority of students did not realise the connection between parts (a) and (b). This part therefore proved to be a good discriminator with only the most able students recognising that Dijkstra's algorithm provides the shortest distance from vertex A to all other vertices, therefore using the two routes A to D and A to H gives the correct route in (b) as DCBABGH, and adding the final values at D and H would give the correct total of 80. Other methods (probably by inspection) tended to lead to a length of at least 82.

Part (c) was generally well answered with the majority of students applying Prim's algorithm correctly starting from vertex E. A few students attempted to construct a table to perform Prim, clearly believing that Prim can only be performed when expressed in matrix form. Finally, there is still a small minority of students who appear to be rejecting arcs when applying Prim's algorithm so scoring only one of the three possible marks in this part. Those students who found the correct minimum spanning tree in (c) usually went on to state the corresponding length in (d).

Question 4

In part (a) the vast majority of students correctly stated the three inequalities but some opted for incorrect strict inequalities.

In part (b) a small minority failed to state the exact coordinates of all the vertices of the feasible region with a number forgetting or ignoring the origin. The non-integer vertices were often given exactly but a minority opted to either read this point off the graph or, after solving the simultaneous equations correctly, only give an answer correct to either 1 or 2 decimal places. In part (c), many students did not do as requested which was to apply the method of point testing with many instead using the objective line method and so scored no marks in this part. Of those that did attempt point testing, many only tested one or two of the three vertices of the feasible region; students are again reminded that this is a methods paper and therefore they must apply all stages of the corresponding algorithm. Even in cases when it is clear that a given vertex, in this case (0, 0), could not possibly be the optimal vertex students must still test all vertices of the feasible region.

Part (d) proved to be extremely discriminating with many students either leaving this part blank or simply guessed the range of possible values for *k*. It was expected that students would either consider

- $2\left(\frac{15}{14}\right)+k\left(\frac{45}{14}\right)\geq 2\left(\frac{5}{2}\right)+k\left(\frac{5}{6}\right)$ (point-testing)

Or

- $-\frac{2}{k}\geq -\frac{5}{3}$ (objective line)

While many students did correctly use one of these two methods many, surprisingly, struggled with the corresponding algebra or, in respect to the case of point-testing, many did not use the exact coordinates so did not achieve the correct answer of $k \geq \frac{6}{5}$.

Question 5

In part (a) most students correctly stated nodes G and K as the places at which the route should start and finish.

Part (b) proved accessible only to the most able students. Many struggled as they could not find the ‘standard’ four odd vertices. Instead careful reading and interpretation of the information given in the question indicated the two additional vertices to be B and D, alongside G and K. The majority just considered the distance between vertices G and K to repeat, and scored no further marks. Students would do well to look at the four marks available in this part and use these as a guide to the amount of work required. Those who did make the connection generally attempted three pairings of the correct four vertices, although some inexplicably only gave two pairings. It was uncommon to see the three correct shortest distances for all three pairings. Common errors were 154 for 139, and 104 or 97 for 96. Those students that gave the correct number of pairings generally stated their arcs that needed to be repeated, although these were not necessarily the correct arcs.

In part (c) very few students stated a correct inspection route but many did go on and access the final mark for considering 601 + their smallest repeat out of a choice of at least two distinct pairings of the correct four nodes from part (b).

Question 6

Examiners reported that a small number of students struggled in applying the first-fit bin packing algorithm in part (a). This was mainly down to not applying the algorithm correctly. First fit is just that; students must decide if the current item under consideration will fit in the first bin rather than the most recent bin used. In this part a number of students placed the 39 in the third bin (and not the second bin) and others did not place the 4 in the first bin.

Full marks in part (b) was rare. Some students completed the full sort rather than stopping after the fourth pass. Others completed four passes on the provided list so effectively obtaining the seventh pass. For those who did carry out the correct number of passes or who made their fourth pass clear, errors were rare. In part (ii) of (b), only the more able students were able to correctly establish that 6 comparisons were needed with most stating that 9 comparisons were required. This demonstrated something of a lack of understanding of how the Bubble Sort works. Deducing that 2 swaps took place seemed more straightforward for most students.

Many correct solutions were seen in part (c), but a number of students did not choose their pivots consistently, switching between middle-left and middle-right pivots during the course of the quick sort algorithm. A number of students either lost an item or changed an item during the sort, and in a small number of cases only one pivot was chosen per iteration. As stated in previous examiners’ reports, in cases such as this in which the list appears to be in the correct order after three passes a fourth pass (pivoting on the 4) is required to successfully complete the algorithm. Students should be reminded that items should remain in the order from the previous pass as they move into sub-lists. Pivots were usually chosen consistently although the spacing and notation on some solutions made these difficult for examiners to follow. Some students over complicated the process by insisting on using a different ‘symbol’ to indicate the pivots for each pass. Those students who sorted into ascending order usually remembered to reverse their list at the end to gain full credit although a number of students left their list in ascending order.

The first-fit decreasing in part (d) was well carried out with only a small minority failing to attempt this part. There were a large number of wholly correct answers. A small number performed first-fit increasing therefore scoring no marks. A small minority of students lost all three marks by placing the 43 in the 3rd rather than 2nd bin (so failing to apply the algorithm at its first real test). Some students wrote totals in the bin rather than the next value. A variety of different layouts were used but in nearly all cases were easy to read and decipher.

Question 7

In part (a) whilst the objective function was found correctly on many occasions, the absence of the word ‘maximise’ meant that the first mark could not be awarded. The first constraint (based on selling few than 200 non-vanilla milkshakes) was usually correct (although many students did not give their answer with a strict inequality). The constraints which required ‘at most 75% of the milkshakes to be vanilla’ and ‘2.5 times as many strawberry as vanilla’ were either dealt with very well by students or not attempted at all. However, simplified inequalities were not always achieved and, on occasion, coefficients were left as fractions rather than integers.
In part (b) many students were able to gain at least the method mark, having found either the correct maximum or minimum profit, in spite of earlier errors in (a). Some fully correct solutions were seen. Errors in this part often resulted from errors in one or more of the constraints in (a). Some students incorrectly assumed that $y = 0$ would lead to the minimum profit.

Question 8

This question was attempted by the vast majority of students suggesting that few students struggled for time. There were a good number of responses which achieved full marks in part (a). However errors, where they arose, were due to a variety of reasons: a lack of arrows on activities or on dummies, extra superfluous dummies (sometimes as many as four or five), incorrect direction of arrows on dummies and incorrect precedence relationships. There were only a few students who produced activity on node diagrams and a small number who attempted to complete the activity network with a single dummy or who produced a network with multiple starts. There appeared to be a fairly common problem, in particular, with the dummy at the start of activity K. This was commonly in the wrong direction. Errors with this dummy were costly as the precedences for activities I and K were subsequently incorrect. Another common error was the placement of a dummy from the end of activity B into the start of activities C and D. Examiners noted the number of students who did not put arrows on their activities and they are reminded of the importance of arrows on activities and on dummies. Students are advised that arrows are best drawn in the middle of arcs as they far clearer than those at the end of arcs.

The vast majority of students which attempted part (b) were correct. There were a small number of attempts who gave a correct calculation but made an arithmetical error to obtain a float of 2 or sometimes 1.

It was pleasing to note the number of students who gave a fully correct response to part (c) although there were a significant number who fell short of the required detail stating, for example, 'not critical because H has a float' perhaps failing to realise that a float of zero is indeed a float. Some thought that ADHIJ was a critical path because it led from source to sink without any dummies or because it was the 'longest' path from source to sink. Others did not answer the question that had been asked, instead defining a critical path. The most concise responses were those that used a numerical argument such as 'ADHIJ is not critical because H has a float of 3'.

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