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General

This paper proved accessible to the candidates. The questions differentiated well, mostly producing a good spread of marks. There were marks available to grade E candidates in all questions and there appeared to be sufficient challenging material for A grade candidates too. It was very rare for a candidate to make no attempt at a question, leaving just blank pages.

As has been stated before, Decision Mathematics examinations are methods-based; consequently, candidates should be reminded that it is vital to display their method clearly. A correct numerical answer, without supporting working demonstrating their method, rarely scores any marks.

Some candidates waste valuable time producing unnecessarily long solutions, for example in the Bubble Sort and Prim's algorithm.

Some very clear well-structured solutions were seen by examiners. Handwriting was generally better than sometimes seen in past sessions, so that it was rare for examiners to struggle to understand what was written by candidates.

Report on individual questions

Question 1

A standard binary search question proved to be a good start of the paper for many candidates, many of whom achieved full marks. This was encouraging given that this area of the specification has not been examined in recent series. Most candidates confidently demonstrated the calculations for middle right pivots and correctly discarded a half list at each stage of the algorithm. It was not necessary for candidates to show their calculations, but this often made working clearer. Most candidates numbered the items in the list from one to ten at the outset and worked with these numbers throughout the application of the algorithm. Others renumbered their sublists at each stage. Both approaches are perfectly acceptable.

Marks were lost by candidates for a range of different reasons. Most surprising were the cases where candidates reached the final stage of the algorithm and concluded that 'parallelogram is found between Diameter and Radius' which lost the final mark and demonstrated perhaps a lack of understanding in the purpose of the Binary Sort Algorithm. Other candidates went as far as inserting parallelogram into the initial list at the start of their working which was a costly error and could earn only the first method mark. There were several errors which cropped up that are more common in Binary Search problems including incorrect retention of pivots when discarding a half list, for example rejecting items 1 – 5 in the first pass rather than 1 – 6. Such 'sticky pivots' can also be costly in terms of loss of marks. Thankfully, instances of sticky pivots were perhaps rarer than in previous series. A small number of candidates appeared to struggle with which half list to discard and so retained the wrong half list during one or more steps of their application of the algorithm. To ward against this, candidates could write out the alphabet at the top of their solution to avoid similar careless errors.

A minority of candidates incorrectly began by choosing a middle left pivot – namely 'Circumference' and a much smaller number of candidates appeared to choose pivots which were neither middle right nor middle left. The algorithm stipulates that in Binary Search, pivots must be middle right and so unfortunately, an alternative pivot earned no marks. Furthermore, there were example of costly carelessness in calculations, for example, '(1+10) / 2 = 6.5 = 7th value = Radius'.

Whilst most candidates clearly selected pivots of one kind or another, there were a small number of candidates who, after calculating $\frac{1+10}{2} = 5.5$, proceeded to chop the list in half which is not a correct application of the Binary Search Algorithm. It is essential that candidates make their choices of pivots clear at each stage whether that be by name or position in the list.

Question 2

Candidates were asked in this question to set up a standard linear programming problem. Most candidates were familiar with the ingredients that were required to formulate the linear programming problem, and many achieved full marks. Unfortunately, however, it was not uncommon for candidates to omit 'minimise' when stating the objective function. Rarely candidates wrote 'minimum' which was not acceptable, but 'min' was condoned.

The constraint for the total number of pizzas appeared to be the most straightforward and most candidates earned this mark. Only in a handful of instances did candidates write the inequality the wrong way around or incorrectly use a strict inequality. The constraint comparing the number of small and large pizzas was a little less well done. There were many correct attempts, but a significant minority of candidates confused either the coefficients of x or y or the direction of the inequality comparing the variables. Many candidates were able to earn at least some credit for either the correct relative coefficients of x and y (for example $y = 2x$ or $y \leq 2x$) or for the correct direction of inequality with interchanged coefficients (namely $2y \geq x$).

Not surprisingly, the third coefficient proved to be the most challenging. Most candidates were well prepared for such constraints and obtained full marks, but a significant minority of candidates seem to struggle with how to correctly convert percentages in constraints into inequalities. Many wrote statements such as $y \leq 80\%(x + y)$ failing to replace 80% with an acceptable fraction or decimal multiplier. Some candidates tried to combine the constraint for the total number of pizzas with the constraint for the large pizzas incorrectly obtaining $y \leq 68$ (which is 80% of 85). A minority of candidates who were able to correctly deal with the 80% did not obtain full marks as they did not simplify their constraint to collect the terms in x and y or to obtain integer coefficients despite being asked to do so in the question. It was not uncommon to see final constraints such as $2y \leq 8x$ which was not penalised.

Question 3

This question was answered well by almost all candidates, with many scoring full marks. The marks most lost were the second mark in (b)(ii) and the final mark in (c). Candidates generally worked accurately, with copying errors, omissions or duplicate items extremely rare.

In (a) a few candidates placed 0.3 incorrectly in either bin 2 or bin 3. Candidates should be reminded to keep checking space in bin 1 in order to follow the algorithm. It was very rare to see a blank solution, or an attempt scoring no marks.

In (b) (i) most candidates readily completed both passes of bubble sort correctly. A surprising minority wasted considerable time writing out many lines of working showing the result of one comparison and swap per line (or showing all passes to fully sort the list).

In (b)(ii) writing down the number of comparisons and swaps prove to be challenging to some candidates, but most gave sensible answers. The most common error was failure to realise that the number of comparisons reduces by one on each consecutive pass.

Almost all candidates applied the quick sort algorithm correctly in (c), most using the right middle pivot, rather than the left. A few candidates excluded the three smallest numbers and were penalised just one mark for this. A substantial minority lost the final mark for failing to complete the algorithm, with either a repeat of their last row or a ‘sort complete’ statement.

In part (d) most candidates gained full marks here. The occasional error was to omit ‘0.3’ from bin 2, placing it in either bin 3 or 4.

Question 4

There were a wide range of marks gained for this question, in part due to the challenge posed in (a). It was also apparent that some candidates lacked an understanding of what is meant by lower and upper bounds, and then how to apply the two named algorithms in parts (b) and (d).

In (a) many candidates skipped this part of the question. Of those who did try there were a good number of perfect answers from those who had learnt the definitions, but also some partially correct suggestions from those who realised that the key feature was the number of times each vertex may be visited. As ever some referred to arcs rather than vertices, therefore gaining no marks. A few candidates focused on strategies to solve the problems, gaining no marks.

Most candidates were able to apply the nearest neighbour algorithm correctly in (b). However, a significant proportion forgot to add the final arc returning to ‘A’, to their route, though some did then add its length. The correct route length (206 km) was often found, though some doubled the route length, without ‘EA’, confusing this with the minimum spanning tree method.

In (c) this mark was only available to those with the correct answer in (b). Whilst some candidates gained this mark with a correct answer and an unambiguous reason, others lost it, claiming that a higher upper bound is better, or giving a contradictory reason.

Many candidates applied Prim’s algorithm correctly in (d), though some failed to delete ‘G’, from their minimum spanning tree. Only a few lost the marks for applying Kruskal’s algorithm instead. Starting from the correct MST, the correct two arcs ‘CG’ and ‘EG’ were usually added, but in a few cases just one of them was added. Full marks were available to those candidates who clearly and correctly combined the two parts of the question.

Similarly, to (c), the mark in (e) was dependent on the correct answer in (d). Responses here tended to mirror answers in (c), with those who believed that a smaller lower bound was better.

In (f) most candidates expressed their answers as an inequality, with only a few using interval notation. Success here generally followed good understanding demonstrated throughout the question, though there were candidates who correctly answered ‘191’ in (e) but then put ‘188’ as their lower number here. Some candidates gained only the first mark on follow through from earlier errors. Others lost the final mark due to having a strict inequality at the upper end of their interval.

Question 5

This was a question of two halves: often candidates were very successful in attempting part (a) but offered much less successful attempts to parts (b) to (f).

In part (a), Dijkstra's algorithm appeared to be well known and most candidates were able to apply the algorithm correctly. The boxes at each node in part (a) were usually completed correctly. When errors were made it was due to the usual reasons: occasionally due to an order of labelling error (some candidates repeated the same labelling at two different nodes), more commonly due to an omission of working values, incorrect order of working values or simply incorrect values stated (usually these errors occurred at nodes E, F and/or J and some candidates failed to take account of the arc from K to J). When errors did arise at early nodes, often the follow through mark could still be awarded for the values in boxes J and H. A small number of candidates believed K to be the final vertex possibly due to the location of K at the bottom right of the network. A few responses worryingly showed no working values whatsoever. This was an expensive mistake and meant no marks could be awarded in part (a).

Many candidates were able to work backwards to correctly state the shortest path from A to H and extract its length from the diagram. This was irrespective of previous errors made with working values or orders of labelling. Most candidates realised that whatever their final value was at H, this was the value that they should give for the length of their route. As noted in previous reports, because the working values are so important in judging the candidate's proficiency in application of the algorithm it would be wise to avoid methods of presentation that require values to be crossed out.

Part (b) required a little more understanding. Whilst many candidates achieved both marks here it was disappointing that quite a few students did not respond to both parts, giving either the route or the length but not both. A common mistake was to omit the first visit to B when stating the route. When calculating the length of the route, some candidates were clearly not using their final values at F and K but instead used the more time-consuming approach of summing the individual arc lengths.

In part (c), candidates were provided with a substantial hint by being asked to 'consider the pairings of all the relevant nodes'. Nonetheless whilst many candidates were able to identify the correct four odd nodes and pair them correctly, a significant number of candidates did not realise that although there were only two odd nodes (C and E), four nodes needed to be considered to allow a start and finish at different nodes (A and J). As a result, there were a significant number of candidates who did not recognise this problem as a route inspection problem and so made the error of considering fewer than the three pairings required (thus considering on the shortest route between C and E). This led to the loss of a significant number of marks. Furthermore, a very small number of candidates considered pairings of the incorrect 4 nodes. For those candidates who did consider the correct nodes, errors in the pairing totals were not uncommon. A common error that arose was for the pairings AJ + CE was where candidates obtained a value of 84 or for AC and EJ to incorrectly total 53. However, errors in the totals often did not affect the choice of repeated arcs which were usually stated correctly. Even though this examination series saw an increase in the number of candidates correctly listing the repeated arcs rather than repeated pairings it was disappointing to see that a significant number of candidates failed to state the new total route length. When it was stated, it was usually correct.

In general parts (d), (e) and (f) were less frequently attempted. For those that did attempt part (d), there was a wide range of answers offered which suggests that candidates were hazarding a guess. The most common route to a correct answer in (d) was half of {6 (the order of F) + 2 (the repeats for EF and FK)}. It was clear that some candidates did not know what was being asked of them as answers such as '41' were seen.

A range of answers (including blanks) were also seen for (d). Not many candidates realised that as D is an even node, if the route starts at D then it will also finish at D.

In part (f), A common incorrect answer was 27 which was found by subtracting both CE (16) and DE (9). Very few candidates gave the correct answer of 36. Those candidates who did answer part (f) correctly usually did show their calculations clearly.

Question 6

This question provided a good opportunity to gain marks and there were few blank responses. The first four parts of this question were reasonably well-accessed, and although a surprising number failed to score any marks at all (usually failing to add any arcs to the diagram), a good number of candidates scored most or all the 10 marks available, with most marks being lost on the schedule in part (e).

Most candidates attempted to draw in activities G, H and I, although some were confused by the early and late event times boxes and were not sure where to start their arcs. Some drew additional early and late event times boxes which led to errors in events at the end of activity F and activity D for part (b). The correct arcs for activities and dummies were used in most cases and very few had missing arrows. A few candidates failed to complete (a) and were thus unable to gain any marks from (a) or (b) as they had oversimplified the question.

Those responses with activities G, H and I drawn correctly generally went on to achieve full marks for (b). Errors with G, H and I meant that at most 3 out of 4 marks were available in (b) but most with errors in (a) often made errors in the early and late times, meaning they only achieved the method marks in (b).

The mark in part (c) for stating the critical activities was achieved by most candidates who had scored marks in part (a) and (b).

Part (d) was completed well with most candidates adding up the activity times and dividing by the finish time. A few tried to divide by the number of activities.

Part (e) was less successful; as in previous years, the scheduling diagram was poorly answered. As well as a significant number of blanks, and some candidates attempting a Gantt chart, many candidates did not manage to make full use of the floats available. Those that ignored the floats failed to use less than 5 workers and so could at best achieve the first method mark. Many others missed off at least one activity. Those that managed to fit all the activities on to the diagram with 4 workers were generally successful with only a few errors occurring, usually with activity J and H overlapping or G starting too early.

Question 7

This was a challenging question, and whilst full marks were rarely scored, many candidates made a good attempt and scored reasonably well. Most candidates attempted part (a) and were generally successful in finding the required inequalities. Point (0,0) was most used to check the direction of the inequality and proved successful.

Some equations were formed incorrectly, giving a positive gradient or an incorrect intercept of 16 or 0.

Part (b), however, saw a huge range of attempts, from several blank or zero responses. The most common approach was to find the coordinates of the optimal vertices of the feasible region, although some failed to ascertain that the intersection of $5y = x + k$ and $y = -2x + 8$ could not provide a maximum and therefore wasted time finding this vertex. Some assumed that the intersection of $5y = x + k$ and $x + y = 8$ would be the optimal vertex without considering the vertex at (0, 8). This meant the maximum they could achieve in this part was 5 out of 7, which seemed to be the modal mark for part (b) with reasonable attempts.

Poor algebra, particularly with fractions, meant that whilst most achieved the method marks, quite a few candidates failed to achieve the coordinates accurately in terms of k and thus ended up with a quadratic in k that they could either not factorise or that had no real solutions.

About half of the candidates who managed to find $k = 4$ (and correctly reject $k = -7$) also found $k = 19/4$, but the vast majority of these did not test their values of k with the optimal vertices to eliminate $k = 19/4$ as well, so full marks was rarely seen.

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