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Oxford Cambridge and RSA

AS/A LEVEL GCE

Examiners' report

MATHEMATICS

3890-3892, 7890-7892

4736/01 Summer 2018 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Paper 4736/01 series overview

4736 is one of the optional applied examinations for 3890 AS Mathematics and 3891 AS Further Mathematics.

This paper tests modelling real-life situations involving: algorithms, graphs and networks, network algorithms and linear programming, commenting on and interpreting the output of the model.

Candidate performance overview

Candidates coped well on this paper; they demonstrated a good understanding of the material and were well prepared for the types of questions that were asked.

Most candidates took care to present their answers neatly. Candidates should be encouraged to make their handwriting legible and not overwrite answers (particularly on diagrams or grids, when a spare grid is provided) as this leaves a result that is impossible to read.

Candidates do need to read each question carefully and answer the question that has been asked and not some related, but different, question.

There was no evidence that candidates were short of time.

Question 1 (i)

1 Pat works at the packing depot for a company that sells shoes. Shops place orders for a number of boxes of shoes and Pat needs to pack the boxes into vans to make the deliveries to the shops. The order from any shop must all be in the same van.

Each van can contain at most 1000 boxes.

Pat has orders for the following numbers of boxes.

Shop	A	B	C	D	E	F	G	H
Boxes	500	400	600	300	300	400	300	200

(i) Demonstrate the use of first-fit to determine a way to pack the orders. Show, using the letters for the shops, which shop's orders are in which van. **[2]**

Question 1 (ii)

(ii) Demonstrate the use of first-fit decreasing to determine a way to pack the orders. **[2]**

Some candidates listed the numbers of boxes instead of showing the letters for the shops. A few used next-fit instead of first-fit and a few used first-fit increasing instead of first-fit decreasing, but most candidates were able to answer these two parts with no problems.

Question 1 (iii)

(iii) Find a packing that uses fewer vans. **[1]**

Question 1 (iv)

(iv) Why might a packing not be practical? **[1]**

Most candidates found a packing that used only three vans but some then focussed on issues that were not related to whether or not the packing was practical. The most appropriate comments were those that considered the locations of the shops and whether the routes taken by the vans were efficient or not.

Question 2 (i)

2 An algorithm involves the following steps.

Step 1 Input positive integers M, N and P.

Step 2 If M is odd, replace P by $P+N$.

Step 3 If M=1 go to step 7.

Step 4 Replace N by $2N$.

Step 5 If M is even, replace M by $M\div2$, otherwise replace M by $(M-1)\div2$.

Step 6 Go to step 2.

Step 7 Output the value of P.

(i) Show the use of the algorithm for the inputs M=8, N=10 and P=3. State the output value of P. **[4]**

Question 2 (ii)

(ii) For inputs M=13, N=n and P=p, what is the output of P in terms of n and p? What is the relationship between the output of P and the original inputs for M, N and P? **[4]**

These two parts were usually done quite well, although some candidates misunderstood the updating operations. Some candidates merged the rows together, which was allowed here but would not have been appropriate if the steps had needed to be identified.

The output needed to be stated and not just implied from the table.

Question 3 (i)

3 A problem to maximise P as a function of x and y (where x and y are both $\geqslant 0$) is represented by the initial Simplex tableau below.

P	x	y	s	t	u	RHS
1	–2	4	0	0	0	0
0	4	–12	1	0	0	12
0	7	–19	0	1	0	35
0	–3	15	0	0	1	0

(i) Write down P as a function of x and y. **[1]**

Question 3 (ii)

(ii) Write down the constraints, apart from non-negativity, as inequalities involving x and y. **[3]**

These two parts were about interpreting the information in the tableau. Some candidates gave a function involving *P*, *x* and *y* rather than *P* as a function of *x* and *y*. Several candidates included the slack variables in the constraints rather than giving inequality constraints.

Question 3 (iii)

(iii) Identify which element should be used as the initial pivot and then carry out one iteration of the Simplex algorithm. **[4]**

Some candidates did not identify the initial pivot. Most candidates were able to carry out the iteration correctly.

Exemplar 1

3 (iii)

B1

	P	x	y	s	t	u	RHS
a	1	−2	4	0	0	0	0
b	0	4 ✓	−12	1	0	0	12
c	0	7	−19	0	1	0	35
d	0	−3 ✗	15	0	0	1	0

$12 \div 4 = 3$

$35 \div 7 = 5$

$0 \div -3 = 0$

A spare copy of this diagram can be found on page 5. M0

M1

	P	x	y	s	t	u	RHS
e	1	0	2	1/2	0	0	6
f	0	1	−3	1/4	0	0	3
g	0	0	−2	7/4	−1	0	−14
h	0	0	6	3/4	0	1	9

(e) $= \frac{1}{2}(b) + (a)$

(g) $= \frac{7}{4}(b) - (c)$

(h) $= \frac{3}{4}(b) + d$

$-9+15$

(answer space continued on next page)

This candidate has chosen the correct pivot and divided through the pivot row by 4, however row 3 of the tableau has been calculated as 7(new pivot row) – original row 3, resulting in the negative of what it should be. Columns *P*, *x*, *t*, *u* should be basis columns, consisting of 0's and a single 1, rather than 0's and some other value, and there should be no negative entries in the final column.

Question 3 (iv)

After a second iteration of the Simplex algorithm the tableau is as given below.

P	x	y	s	t	u	RHS
1	0	0	$\frac{3}{4}$	0	$\frac{1}{3}$	9
0	1	0	$\frac{5}{8}$	0	$\frac{1}{2}$	$7\frac{1}{2}$
0	0	0	-2	1	$-\frac{1}{3}$	11
0	0	1	$\frac{1}{8}$	0	$\frac{1}{6}$	$1\frac{1}{2}$

(iv) Write down the values of P, x, y, s, t and u after this second iteration. **[2]**

Some candidates wrote the values from their tableau in part (iii) and some wrote the values from the objective row, but most were able to interpret the tableau appropriately.

Question 3 (v)

(v) Show that the values of x and y from part **(iv)** satisfy the constraints from part **(ii)** and interpret the values of s, t and u. **[4]**

Candidates usually substituted their values of *x* and *y* into the constraints and showed that they were satisfied, but several did not interpret the values of *s*, *t* and *u*, or just said that these are the slack variables.

Exemplar 2

3(v)

$4x - 12y \le 12$

$30 - 12(1.5) = 12$, $12 = 12$ there is no slack here and so $s = 0$.

$7x - 19y \le 35$.

$7(7.5) - 19(1.5) = 24 \le 35$ there is a slack of $35 - 24 = 11$ here which means $t = 11$.

$-3x + 15y \le 0$

$-3(7.5) + 15(1.5) = 0$, $0 = 0$, there is no slack so $u = 0$.

This candidate has shown that LHS $\le$ RHS for each inequality and also has interpreted the values of *s*, *t* and *u*.

Question 4 (i)

4 The running costs (in £million) of 10 bus routes between six locations in a city are shown in the table below. A blank indicates that there is no bus route between the locations. The route between the university and the museum is new and therefore its running costs are currently unknown, this is labelled as x.

		M	N	P	R	S	U
Museum	M			6		7	x
Nautical centre	N				5	4	8
Park and ride	P	6			3	2	
Railway station	R		5	3		4	8
Shopping centre	S	7	4	2	4		
University	U	x	8		8		

To save money the bus company are planning to cut some of the bus routes. Assume that there is no change in the running costs of the remaining bus routes.

(i) What is the minimum number of bus routes that must operate so that it is still possible to travel between the six locations? **[1]**

This part was about understanding the relationship between the network model and the problem that it represents. In this case the vertices represent locations and the arcs represent bus routes.

For the minimum number of routes the remaining network must form a spanning tree. With six vertices this will have five arcs.

Question 4 (ii)

(ii) Apply Prim's algorithm to the reduced table for which the row and column representing the university have been removed. Start by crossing out the row for M and choosing an entry from the column for M. Write down the arcs used in the order that they are chosen. Draw the resulting minimum spanning tree and give its total weight. **[5]**

Some candidates did not show the application of Prim's algorithm to the reduced table and some wrote the vertices (in the order that they were chosen) instead of the arcs. Several candidates used nearest neighbour instead of Prim and ended up with a tree of total weight 17 instead of total weight 15.

Some candidates gave the total weight as £15 million, the total running cost for these routes, instead of giving the sum of the arc weights in the network model.

Question 4 (iii)

(iii) Give the value of x for which the spanning tree for all six locations has total weight 21. **[1]**

Many correct responses, following through the tree weight from part (ii), provided it gave a value of x that was less than 8.

Question 4 (iv)

(iv) Give the value of x for which a most expensive bus route would be included in the minimum spanning tree for all six locations. **[1]**

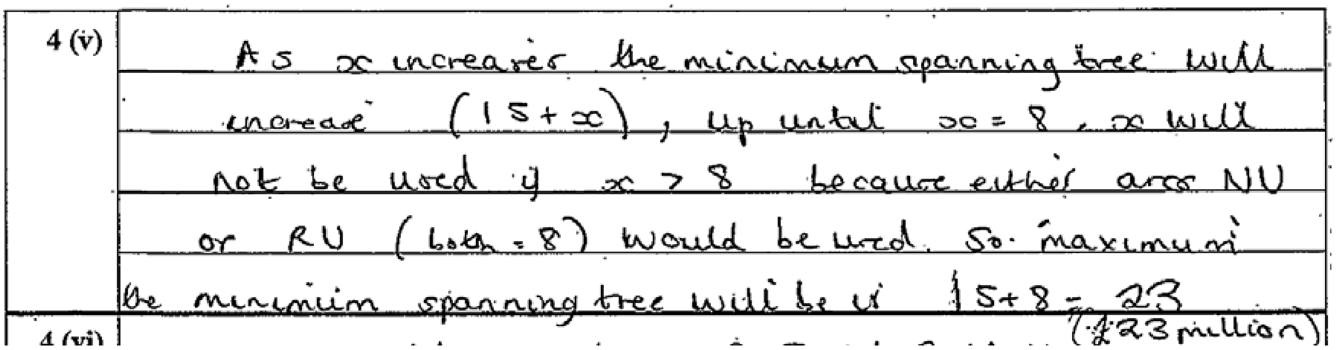
The value of x is continuous and a most expensive route would be included in the tree as soon as $x = 8$. There were the usual issues with candidates claiming 7 or 9 and a few who claimed 8.1 or similar.

Question 4 (v)

(v) Describe in detail what happens to the total weight of the minimum spanning tree for all six locations as the value of x increases. **[2]**

The key phrase here is 'in detail'. Many of the responses were not detailed enough, just saying 'it increases' without giving any further detail.

Exemplar 3


4 (v)

As x increases the minimum spanning tree will increase $(15 + x)$, up until $x = 8$, x will not be used if $x > 8$ because either arc NU or RU (both = 8) would be used. So maximum the minimum spanning tree will be is $15+8 = 23$ (£23 million)

4 (vi)

This candidate has explained what happens for each of the cases $x < 8$ and $x \geq 8$. The (£23 million) is wrong but was not penalised as a correct answer had already been achieved by line 4 of the response.

Question 4 (vi)

(vi) Assume that x is less than the value from part **(iv)**. Use the nearest neighbour method, starting at P to find, in terms of x, an upper bound for the least cost cycle that connects the six locations. **[2]**

Many correct responses. A few that did not close the cycle and some that did not start at *P* or that used a diagram and did not show the direction of travel. Listing the vertices travelled through is usually the best approach. Some candidates did not like giving an answer in terms of x and chose a specific value (such as 7) for x, even though the question said to find an upper bound in terms of x.

Question 4 (vii)

(vii) Use the information in the table to draw a graph to show which locations are connected by bus routes. **[1]**

Most candidates were able to draw a suitable graph. Some candidates missed out an arc and some worried about trying to draw a planar graph, but most gave the graph as in the mark scheme.

Question 4 (viii)

(viii) Draw a subgraph of your answer to part **(vii)** that is a tree connecting all six locations in which no location is more than two bus routes from the university. **[1]**

Many correct responses. Some candidates overlooked the requirement that no location is more than two bus routes from the university and some used at least one arc that was not in the original graph, often arc US, and hence had not given a subgraph.

Question 5 (i)

5 Jimmy has made a batch of marmalade to sell to raise money for charity. He wants to raise as much money as possible.

He has enough marmalade to fill 40 small jars or 30 large jars. He has enough jars so that he could use all small jars or all large jars or a mixture of small and large jars.

Jimmy knows that small jars are more popular than large jars so he wants to fill at least as many small jars as large jars. He can only carry at most 36 jars in total.

He intends to charge £2 for each small jar and £3 for each large jar. It costs Jimmy a total of £12 to make each batch of marmalade. He expects to be able to sell all the jars he fills.

Let x denote the number of small jars that Jimmy fills and y denote the number of large jars.

(i) Show why the constraint $3x + 4y \leqslant 120$ is needed. Write down the other constraints on the values of x and y, apart from needing to be integer valued. **[4]**

There are several correct ways to answer the first part of this question, and several incorrect ways to manipulate the numbers in the question to achieve the expression given. Broadly, candidates needed to either use 'units' (units produced or unit costs), which come from a scaled version of $\frac{x}{40}+\frac{y}{30}\leq 1$, or consider ratios (1 small jar holds $\frac{3}{4}$ of the amount in a large jar). In both cases these then needed to be shown to lead to the given result.

Most candidates achieved at least one and often two of the other constraints, but non-negativity (for both x and y) was often overlooked.

Question 5 (ii)

(ii) Write down an objective function P, in terms of x and y, where P is to be maximised. **[1]**

A suitable objective function was generally given, usually $P = 2x + 3y$ or $P = 2x + 3y - 12$.

Question 5 (iii)

(iii) Plot the feasible region graphically. **[4]**

Some candidates drew the boundary $y = x$ passing through the top corner (45, 40) instead of (40, 40) and there were some inaccurate lines, but most candidates were able to plot the constraints that they knew about. Several candidates assumed that the feasible region was one of the small triangles or did not indicate a feasible region at all.

Question 5 (iv)

(iv) Use your graph to find how many small jars and how many large jars Jimmy should fill. **[3]**

Many candidates calculated the intersections and then either used a sliding profit line or checked the value of *P* at the vertices of the feasible region. Most realised that the number of jars needed to be positive integers, but some just rejected the solution at $\left(\frac{120}{7}, \frac{120}{7}\right)$ instead of substituting it with an adjacent feasible integer-valued point, ideally (17, 17).

The solution at (20, 15) was allowed as a special case but candidates who gave this had not usually made it evident how they had used the graph.

Question 5 (v)

(v) How much profit can Jimmy expect to make? **[1]**

The maximum profit is £73. Some candidates forgot to subtract the £12 cost for making the batch.

Question 6 (a) (i)

6 **(a)** The network in Fig. 1 represents a system of one-way streets in a city centre. The vertices represent roundabouts, the arcs represent roads and the weights show distances in units of 100 m.

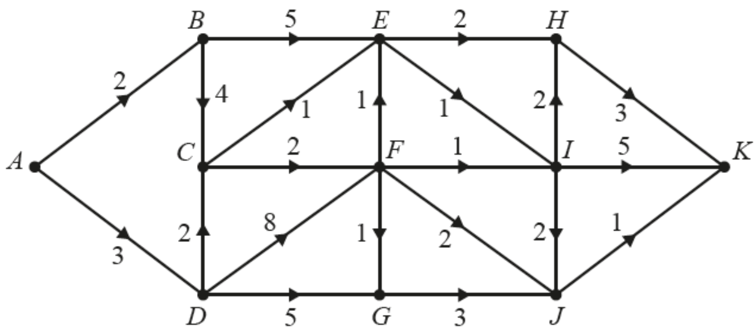


Fig. 1

(i) Apply Dijkstra's algorithm to the network, starting at A, to find the shortest distance from A to K (in units of 100 m) and write down the route(s) of the shortest path(s). **[6]**

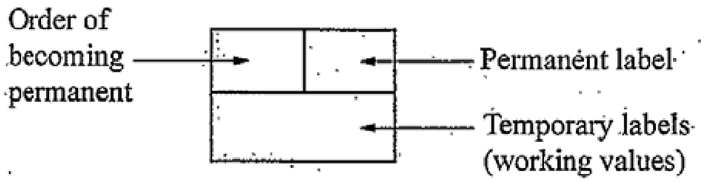
Candidates often made numerical errors in applying Dijkstra's algorithm. There is no need to record the route taken as part of the labelling; this is done by tracing back at the end.

There were two shortest paths from A to K, each of weight 10. Most candidates who achieved the permanent label at K as 10 were able to find at least one of these.

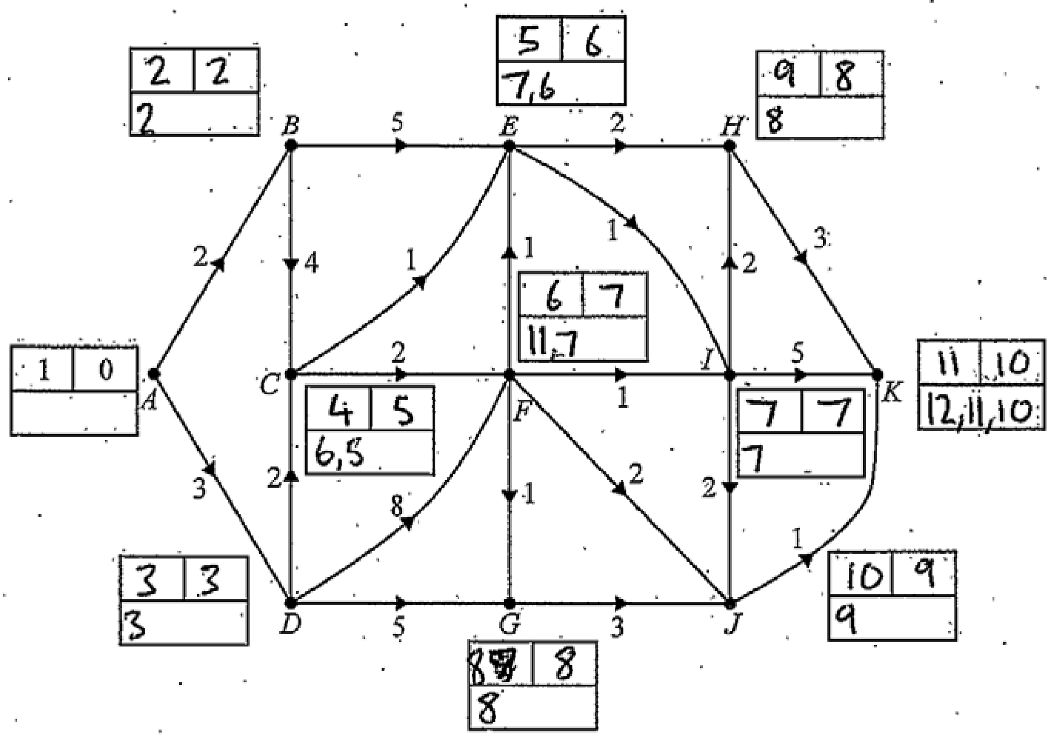
Exemplar 4

6 (a)(i)

Key:



Do not cross out your temporary labels.



Shortest distance: 10 (in units of 100 m)

Route(s): A → D → C → F → J → K

A → D → C → E → I → K

This is a correct response.

Question 6 (a) (ii)

Roadworks mean that the roundabout at C is not available.

(ii) By considering the shortest distance from A to each of E, F and G, when vertex C is not available, find the shortest distance from A to K (in units of 100 m) and write down the route(s) of the shortest path(s). [You do not need to use Dijkstra's algorithm to find the shortest distances.] **[4]**

There were a variety of responses. Many candidates completely ignored the instruction to consider the shortest distance from *A* to each of *E*, *F* and *G*. Several candidates also overlooked the fact that vertex *C* is not available and gave routes that passed through *C*.

The shortest distance was 11 (units of 100 m) and there was just one suitable route. Candidates who thought that the shortest distance was 12 had a choice of two routes, but could still gain partial credit for an appropriate 'first half'.

Question 6 (b) (i)

(b) Cycle lanes allow cyclists to travel in either direction on the roads.

While the roundabout at C is not available the undirected network is as shown in Fig. 2.
The total weight of the arcs shown in Fig. 2 is 47.

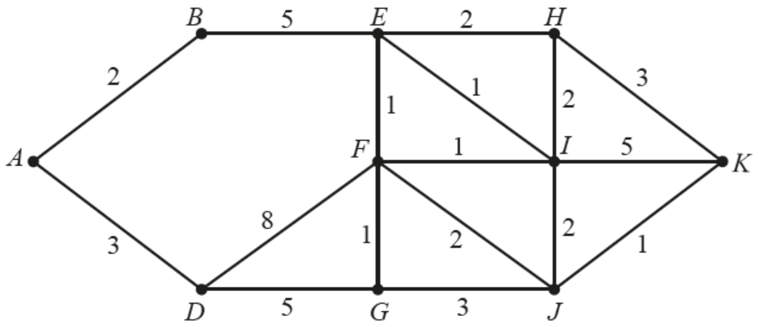


Fig. 2

(i) A cyclist wants to travel along every road at least once in a continuous route that starts and ends at A. Given that arc DG must be travelled exactly twice, apply the route inspection algorithm, showing your working, to find the minimum distance that the cyclist would need to travel. Write down all the arcs that represent roads that would be repeated in this minimum route. **[4]**

Several candidates ignored the instruction to 'apply the route inspection algorithm, showing your working' and just gave the repeated arcs for the minimum distance.

Similarly, when asked to 'write down all the arcs that represent roads that would be repeated', some candidates forgot to write down DG.

Question 6 (b) (ii)

The roadworks at C finish, so C and all the arcs connected to C are available again.

(ii) Find the minimum distance that a cyclist would need to travel to pass along every road at least once in a continuous route that starts at B and ends at E. How many times does this route travel on the roundabout represented by vertex F? **[3]**

Only a few candidates gave full explanations of their method. With *C* reconnected, the total weight of the network is now 47 + 9 = 56 and the odd vertices are *B*, *E*, *G*, *H*, *I*, *K*.

The route needs to start and end at *B* and *E*, so the pairings of *G*, *H*, *I*, *K* needed to be considered. This gave a minimum distance of 61, with *F* being passed through four times.

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