

Paper Reference 9FM0/3D
Pearson Edexcel
Level 3 GCE

Further Mathematics
Advanced
PAPER 3D: Decision Mathematics 1

Friday 20 June 2025 – Afternoon

Time: 1 hour 30 minutes

Question Paper

**THIS DOCUMENT MUST NOT BE RETURNED TO
PEARSON AT THE END OF THE EXAMINATION.**

YOU MUST HAVE

**Mathematical Formulae and Statistical Tables (Green),
calculator**

YOU WILL BE GIVEN

Diagram Booklet

Answer Booklet

Candidates may use any calculator permitted by Pearson regulations. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

INSTRUCTIONS

In the boxes on the Answer Booklet and on the Diagram Booklet, write your name, centre number and candidate number.

Do not return the Question Paper with the Answer Booklet.

Answer ALL questions and ensure that your answers to parts of questions are clearly labelled.

Answer the questions in the Answer Booklet or in the separate Diagram Booklet – there may be more space than you need.

Do NOT write on this Question Paper.

You should show sufficient working to make your methods clear. Answers without working may not gain full credit.

Inexact answers should be given to three significant figures unless otherwise stated.

INFORMATION

A booklet ‘Mathematical Formulae and Statistical Tables’ is provided.

There are 7 questions in this Question Paper.

The total mark for this paper is 75

**The marks for EACH question are shown in brackets
– use this as a guide as to how much time to spend on
each question.**

There are two copies of all diagrams.

ADVICE

Read each question carefully before you start to answer it.

Try to answer every question.

Check your answers if you have time at the end.

1.

4·7	2·9	5·5	1·4	5·8	2·8
3·8	6·5	5·1	6·3	4·1	

(a) Use the first–fit bin packing algorithm to determine how the numbers listed above can be packed into bins of size 13
(3 marks)

(b) Use the first–fit decreasing bin packing algorithm to determine how the numbers listed above can be packed into bins of size 13
(2 marks)

(Total for Question 1 is 5 marks)

2.

271	828	182	845	904
523	536	028	747	135

The list of ten numbers above is to be sorted into descending order.

(a) Perform a quick sort on the list to obtain the sorted list.

You should show the result of each pass and identify the pivots clearly.

(4 marks)

A list of n numbers is to be sorted into descending order using bubble sort.

(b) Determine, in the worst case, the total number of comparisons required to sort the list.

Give your answer as a simplified expression in terms of n

(2 marks)

(continued on the next page)

2. continued.

The following algorithm determines an approximation to the value of **e**

Step 1	Start
Step 2	Let $a = 1$
Step 3	Let $b = 1$
Step 4	Let $c = 1$
Step 5	Let $d = a$
Step 6	Let $c = c \times b$
Step 7	Let $d = d + \frac{1}{c}$
Step 8	If $b = 6$ go to Step 11
Step 9	Let $b = b + 1$
Step 10	Go to Step 6
Step 11	Output d
Step 12	Stop

(continued on the next page)

2. continued.

(c) Refer to Diagram 1 in the Diagram Booklet.

It shows a table.

Complete the table to show the results obtained at each step of the algorithm on the previous page.

(3 marks)

(d) Calculate, to 3 significant figures, the percentage error in using the value found in (c) to approximate the value of e

(1 mark)

(Total for Question 2 is 10 marks)

3. Refer to Diagram 2 in the Diagram Booklet.

Direct roads between seven villages, A, B, C, D, E, F and G, are represented in Diagram 2

The weight on each arc is the time, in minutes, taken to travel along the corresponding road.

Three roads, AB, AD and GE, are one-way, as indicated by the arrow on the corresponding arc.

Floyd's algorithm is to be used to find the complete network of shortest times between the seven villages.

- (a) Set up an initial time matrix for this network using the table in the Answer Booklet.**
(2 marks)

(continued on the next page)

3. continued.

Refer to Diagram 3 in the Diagram Booklet.

The time matrix after three iterations of Floyd's algorithm is shown in Diagram 3

(b) Perform the next two iterations of Floyd's algorithm that follow from the table shown in Diagram 3

You should show only the time matrix after each iteration using the tables in the Answer Booklet.

(5 marks)

(continued on the next page)

3. continued.

Refer to Diagram 4 in the Diagram Booklet.

The final time matrix after completion of Floyd's algorithm is shown in Diagram 4

Albert must visit each village.

He will start and finish at B and wishes to minimise the total time taken to visit each village.

(c) (i) Use the nearest neighbour algorithm, starting at B, to find a Hamiltonian cycle in the complete network of shortest times shown in Diagram 4

(ii) Find the total travel time for this cycle.

(iii) Given that he travels the Hamiltonian cycle found in (c)(i), interpret this cycle in terms of the actual villages visited by Albert.

(3 marks)

(Total for Question 3 is 10 marks)

4. Refer to Diagram 5 and Diagram 6 in the Diagram Booklet.

Diagram 5 represents a network of corridors between 10 offices, A, B, C, D, E, F, G, H, J and K, in a building.

The number on each edge represents the length, in metres, of the corresponding corridor.

On Monday morning, Turvi needs to walk from J to K via A

She wishes to minimise the distance she travels along the corridors.

- (a) (i) Use Dijkstra's algorithm and Diagram 6 in the Diagram Booklet, starting at A, to find the shortest route from J to K via A

- (ii) State the length of this route.

(6 marks)

(continued on the next page)

4. continued.

On Monday afternoon, Turvi needs a route that traverses each corridor at least once.

She plans to start at J and finish at A and wants to minimise the distance travelled.

(b) (i) By considering the pairings of all relevant nodes, find the corridors that would need to be traversed twice.

You must make your method and working clear.

(ii) State the total length of this route.

(5 marks)

(continued on the next page)

4. continued.

Turvi discovers that she cannot walk along corridors **AB, **CD** and **JK** because they are being decorated.**

Turvi walks from **J to **A** travelling along all the other corridors at least once.**

She does this in the minimum distance possible.

(c) Determine the difference between the length of the route Turvi travels and the length of the route found in (b).

You must make the values used in your calculation clear.

(2 marks)

(Total for Question 4 is 13 marks)

5. Consider the following linear programming problem in x , y and z

$$\text{Maximise } P = 3x + 4y + 2z$$

subject to

$$2x + 2y + 2z \leq 21$$

$$2x - y - z \leq 18$$

$$-3x + y - 2z \leq 1$$

$$x \geq 4 \quad y \geq 1 \quad z \leq -3$$

- (a) Explain why the Simplex algorithm cannot be used to solve this linear programming problem in its current form.

(1 mark)

(continued on the next page)

5. continued.

- (b) Use the substitutions $x = X + 4$, $y = Y + 1$, $z = -Z - 3$ and $P = Q + 10$ to reformulate the linear programming problem into a form in which the Simplex algorithm can be used to solve the problem.

You should write the constraints as simplified inequalities with integer coefficients.

(3 marks)

(continued on the next page)

5. continued.

Refer to Diagram 7 in the Diagram Booklet.

After a second iteration of the Simplex algorithm, a possible tableau T is shown in Diagram 7

**(c) Write down the profit equation given by T
(1 mark)**

**(d) Using your answer to (c), explain why T is not optimal.
(1 mark)**

(e) (i) Perform the third iteration of the Simplex algorithm using the tables in the Answer Booklet.

You should state the row operations you use.

(ii) Hence determine the maximum value of P , and the corresponding values of x , y and z

(6 marks)

(Total for Question 5 is 12 marks)

6. Refer to Diagram 8 in the Diagram Booklet.

A project is modelled by the activity network shown in Diagram 8

The activities are represented by the arcs.

The number in brackets on each arc gives the time, in hours, to complete the corresponding activity.

The project is to be completed in the shortest possible time.

- (a) Complete Table 1 in the Answer Booklet to show the immediately preceding activities for each activity.**

(2 marks)

- (b) Refer to Diagram 9 in the Diagram Booklet. Complete Diagram 9 to show the early event times and the late event times.**

(4 marks)

(continued on the next page)

6. continued.

(c) Refer to Diagram 10 in the Diagram Booklet.

Draw a Gantt chart for this project on Diagram 10.

(4 marks)

Refer to Diagram 11 in the Diagram Booklet.

The resource histogram in Diagram 11 shows the number of workers required when each activity starts at its earliest possible time.

When an activity is started it must be completed without interruption.

Each activity requires at least one worker.

(d) By considering which activities are happening each hour, and by working backwards from the minimum project completion time, complete Table 2 in the Answer Booklet to show the number of workers needed for each activity.

(3 marks)

(Total for Question 6 is 13 marks)

7. Refer to Diagram 12 in the Diagram Booklet.
It shows the constraints of a linear programming problem in x and y , where R is the feasible region.

The objective is to maximise

$P = 11x + ky$, where k is a positive constant.

The optimal value of P is to be found using the big- M method.

- (a) Set up an initial tableau in the Answer Booklet for solving this linear programming problem using the big- M method.

You should use exactly 2 slack variables,
2 surplus variables and 2 artificial variables.
(7 marks)

(continued on the next page)

7. continued.

Refer to Diagram 13 in the Diagram Booklet.

After a third iteration of the big-M method, a possible tableau is shown in Diagram 13

(b) Given that the third iteration gives the optimal value for P , determine this value.

(5 marks)

(Total for Question 7 is 12 marks)

TOTAL FOR PAPER IS 75 MARKS

END OF PAPER