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EDEXCEL A LEVEL FURTHER MATHEMATICS: QUESTIONS BY TOPIC

## Dynamic Programming (4)

### Decision Mathematics 2 · Topic 4

11 questions · 116 marks · Mark schemes included

*Pearson Edexcel A Level Further Mathematics (9FM0), June 2019 - June 2025*

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**HOW TO USE THIS BOOKLET**

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

| QUESTION                         | SOURCE                                         | MARKS             | PAGE      |
|----------------------------------|------------------------------------------------|-------------------|-----------|
| <b>4.1 DYNAMIC PROGRAMMING</b>   |                                                | 11 Qs · 116 marks | <b>3</b>  |
| 1. <b>Q1</b> <i>also Topic 2</i> | Option 4D: Decision Mathematics 2 June2022     | 6                 | <b>4</b>  |
| 2. <b>Q2</b> <i>also Topic 2</i> | Option 4D: Decision Mathematics 2 June2019     | 7                 | <b>5</b>  |
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| 10. <b>Q6</b>                    | Option 4D: Decision Mathematics 2 June2022     | 14                | <b>13</b> |
| 11. <b>Q5</b>                    | Option 4D: Decision Mathematics 2 June2025     | 13                | <b>14</b> |



# QUESTIONS

11 questions · 116 marks · 1 sub-topics



SUB-TOPIC 4.1

# DYNAMIC PROGRAMMING

Sub-topic 4.1 · 11 questions · 116 marks · lowest tariff first



1. Four workers, A, B, C and D, are to be assigned to four tasks, 1, 2, 3 and 4. Each task must be assigned to just one worker and each worker must do only one task.

The cost of assigning each worker to each task is shown in the table below.

The total cost is to be minimised.

|   | 1  | 2  | 3  | 4  |
|---|----|----|----|----|
| A | 32 | 45 | 34 | 48 |
| B | 37 | 39 | 50 | 46 |
| C | 46 | 44 | 40 | 42 |
| D | 43 | 45 | 48 | 52 |

- (a) Reducing rows first, use the Hungarian algorithm to obtain an allocation that minimises the total cost. You must make your method clear and show the table after each stage.

(5)

- (b) State the minimum total cost.

(1)

(Total for Question 1 is 6 marks)



2. Four workers, Ted (T), Harold (H), James (J) and Margaret (M), are to be assigned to four tasks, 1, 2, 3 and 4. Each worker must be assigned to just one task and each task must be done by just one worker.

The profit, in pounds, resulting from allocating each worker to each task, is shown in the table below. The profit is to be maximised.

|   | 1   | 2   | 3   | 4   |
|---|-----|-----|-----|-----|
| T | 103 | 97  | 74  | 80  |
| H | 201 | 155 | 145 | 155 |
| J | 111 | 80  | 77  | 92  |
| M | 203 | 188 | 137 | 184 |

- (a) Reducing rows first, use the Hungarian algorithm to obtain an allocation that maximises the total profit. You must make your method clear and show the table after each stage.

(6)

- (b) Determine the resulting total profit.

(1)

(Total for Question 2 is 7 marks)



1. Four workers, A, B, C and D, are to be assigned to four tasks, 1, 2, 3 and 4. Each worker must be assigned to exactly one task and each task must be done by exactly one worker.

Worker A cannot do task 3 and worker B cannot do task 4

The table below shows the profit, in pounds, that each worker would earn if assigned to each of the tasks.

|   | 1  | 2  | 3  | 4  |
|---|----|----|----|----|
| A | 29 | 20 | –  | 23 |
| B | 32 | 30 | 28 | –  |
| C | 35 | 32 | 34 | 25 |
| D | 29 | 31 | 27 | 30 |

- (a) Reducing rows first, use the Hungarian algorithm to obtain an allocation that maximises the total profit. You must make your method clear and show the table after each stage.

(7)

- (b) Determine the resulting total profit.

(1)

(Total for Question 1 is 8 marks)



4. Four students, A, B, C and D, are to be allocated to four rounds, 1, 2, 3 and 4, in a competition. Each student is to take part in exactly one round and no two students may play in the same round.

Each student has been given an estimated score for each round. The estimated scores for each student are shown in the table below.

|   | 1  | 2  | 3  | 4  |
|---|----|----|----|----|
| A | 34 | 20 | 18 | 15 |
| B | 49 | 31 | 12 | 34 |
| C | 48 | 27 | 23 | 26 |
| D | 52 | 45 | 42 | 42 |

- (a) Reducing rows first, use the Hungarian algorithm to obtain an allocation that maximises the total estimated score. You must make your method clear and show the table after each stage.

(7)

- (b) Find this total estimated score.

(1)

(Total for Question 4 is 8 marks)



6.

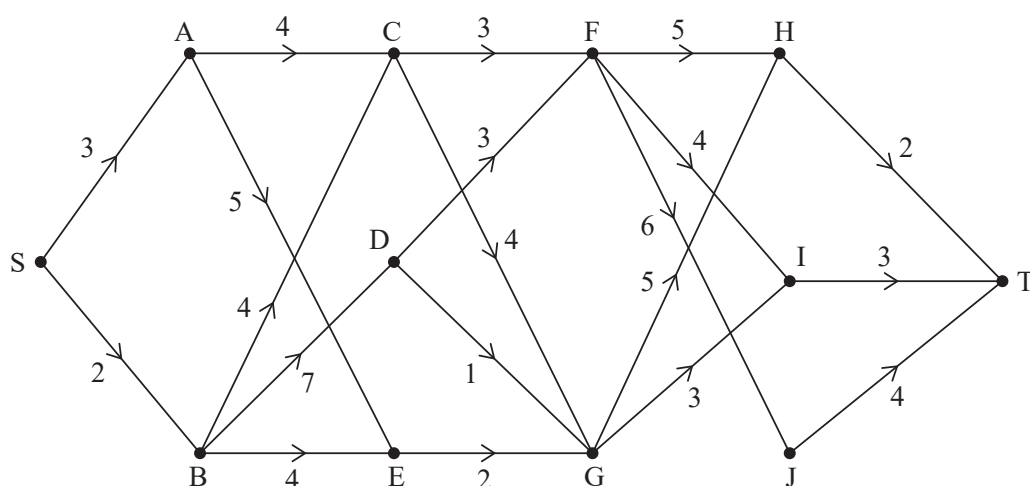


Figure 2

The staged, directed network in Figure 2 represents the roads that connect 12 towns, S, A, B, C, D, E, F, G, H, I, J and T. The number on each arc shows the time, in hours, it takes to drive between these towns.

Elena plans to drive from S to T. She must arrive at T by 9 pm.

- (a) By completing the table in the answer book, use dynamic programming to find the latest time that Elena can start her journey from S to arrive at T by 9 pm.

(9)

- (b) Hence write down the route that Elena should take.

(1)

(Total for Question 6 is 10 marks)



6.

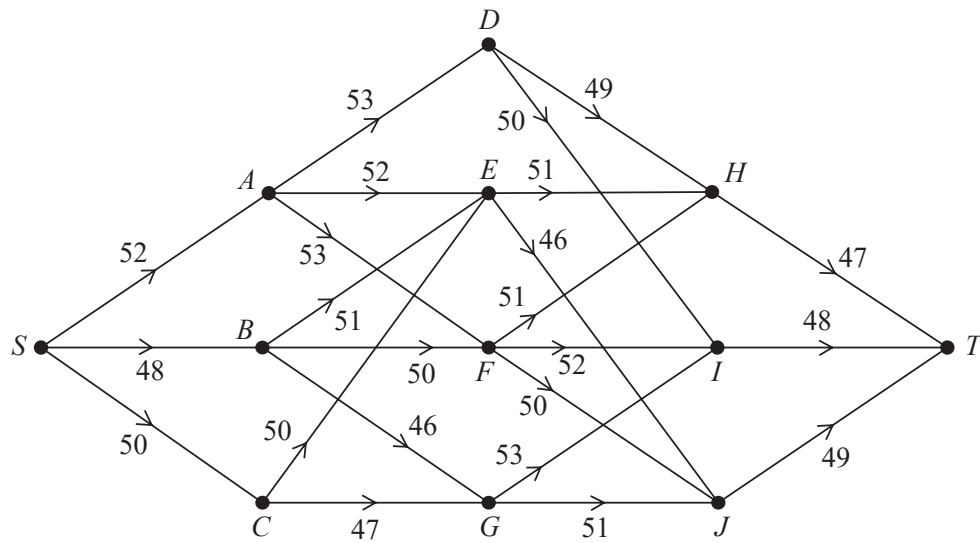


Figure 3

The staged, directed network in Figure 3 represents a series of roads connecting 12 towns,  $S, A, B, C, D, E, F, G, H, I, J$  and  $T$ . The number on each arc shows the distance between these towns, in miles.

Bradley is planning a four-day cycle ride from  $S$  to  $T$ .

He plans to leave his home at  $S$ . On the first night he will stay at  $A, B$  or  $C$ , on the second night he will stay at  $D, E, F$  or  $G$ , on the third night he will stay at  $H, I$  or  $J$ , and he will arrive at his friend's house at  $T$  on the fourth day.

Bradley decides that the maximum distance he will cycle on any one day should be as small as possible.

- Write down the type of dynamic programming problem that Bradley needs to solve. (1)
- Use dynamic programming to complete the table in the answer book. (9)
- Hence write down the possible routes that Bradley could take. (2)

(Total for Question 6 is 12 marks)



7. A manufacturer can export five batches of footwear each year. Each exported batch contains just one type of footwear. The types of footwear are trainers, sandals or high heels.

The table below shows the profit, in £1000s, for the number of batches of each type of footwear.

| Number of batches | 0 | 1  | 2   | 3   | 4   | 5   |
|-------------------|---|----|-----|-----|-----|-----|
| Trainers          | 0 | 50 | 90  | 170 | 225 | 295 |
| Sandals           | 0 | 70 | 110 | 165 | 245 | 300 |
| High heels        | 0 | 75 | 115 | $x$ | 235 | 305 |

The total annual profit is to be maximised.

- (a) Use dynamic programming to determine the two possible values of the maximum total annual profit, giving one of these values in terms of  $x$ .

(10)

Given that the maximum total annual profit is £320 000

- (b) advise the manufacturer on the possible ways in which the five batches should be allocated.

(2)

(Total for Question 7 is 12 marks)



3.

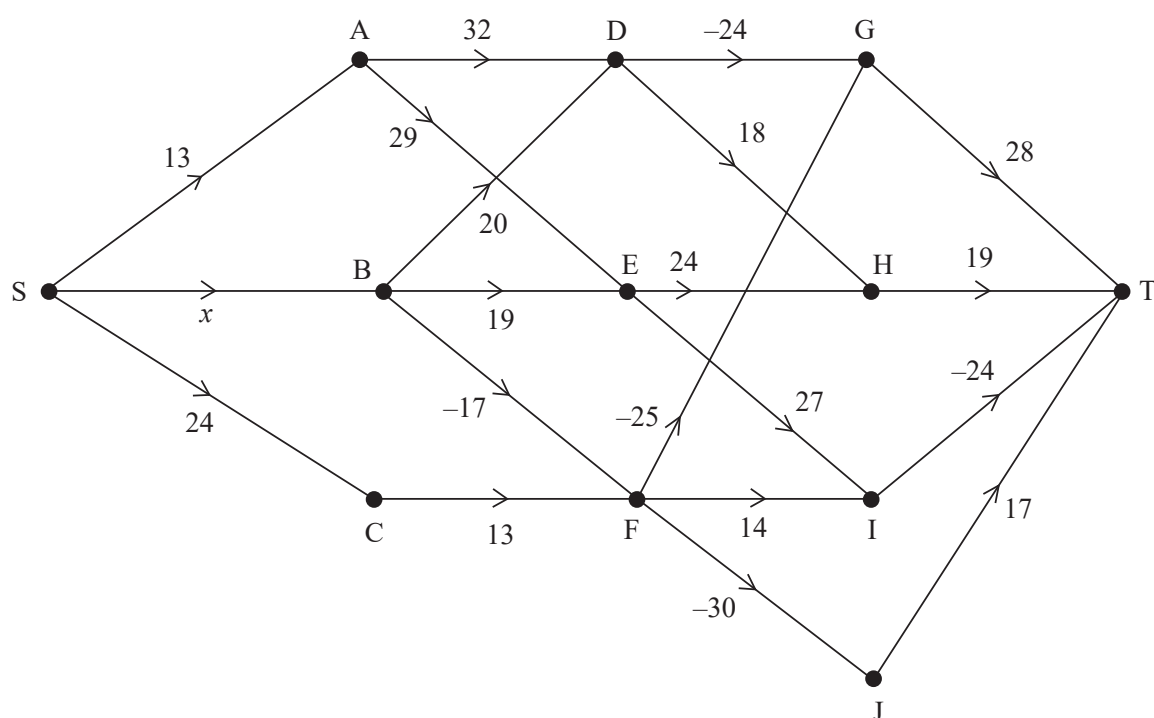


Figure 1

In Figure 1 the weight of arc SB is denoted by  $x$  where  $x \geq 0$

- (a) Explain why Dijkstra's algorithm cannot be used on the directed network in Figure 1. (1)

It is given that the minimum weight route from S to T passes through B.

- (b) Use dynamic programming to find

- (i) the range of possible values of  $x$
- (ii) the minimum weight route from S to T.

(12)

(Total for Question 3 is 13 marks)



6. Polly is a motivational speaker who is planning her engagements for the next four weeks.

Polly will

- visit four different countries in these four weeks
- visit just one country each week
- leave from her home, S, and return there only after visiting the four countries
- travel directly from one country to the next

Polly wishes to determine a schedule of four countries to visit.

Table 1 shows the countries Polly could visit each week.

| Week                        | 1      | 2         | 3      | 4         |
|-----------------------------|--------|-----------|--------|-----------|
| Possible countries to visit | A or B | C, D or E | F or G | H, I or J |

**Table 1**

Table 2 shows the speaker fee, in £100s, Polly would expect to earn in each country.

| Country           | A  | B  | C  | D  | E  | F  | G  | H  | I  | J  |
|-------------------|----|----|----|----|----|----|----|----|----|----|
| Earnings in £100s | 47 | 45 | 48 | 47 | 49 | 44 | 45 | 47 | 49 | 48 |

**Table 2**

Table 3 shows the cost, in £100s, of travelling between the countries.

|   | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| S | 5 | 2 |   |   |   |   |   | 7 | 8 | 8 |
| A |   |   | 3 | 4 | 5 |   |   |   |   |   |
| B |   |   | 5 | 4 | 6 |   |   |   |   |   |
| C |   |   |   |   |   | 7 | 5 |   |   |   |
| D |   |   |   |   |   | 6 | 7 |   |   |   |
| E |   |   |   |   |   | 7 | 6 |   |   |   |
| F |   |   |   |   |   |   |   | 6 | 7 | 8 |
| G |   |   |   |   |   |   |   | 7 | 8 | 6 |

**Table 3**

Polly's expected income is the value of the speaker fee minus the cost of travel.

She wants to find a schedule that maximises her total expected income for the four weeks.

Use dynamic programming to determine the optimal schedule. Complete the table provided in the answer book and state the maximum expected income.

(13)

(Total for Question 6 is 13 marks)



6. Bernie makes garden sheds. He can build up to four sheds each month.

If he builds more than two sheds in any one month, he must hire an additional worker at a cost of £250 for that month.

In any month in which sheds are made, the overhead costs are £35 for each shed made that month.

A maximum of three sheds can be held in storage at the end of any one month, at a cost of £80 per shed per month.

Sheds must be delivered at the end of the month.

The order schedule for sheds is

| Month          | January | February | March | April | May |
|----------------|---------|----------|-------|-------|-----|
| Number ordered | 1       | 3        | 3     | 5     | 2   |

There are no sheds in storage at the beginning of January and Bernie plans to have no sheds left in storage after the May delivery.

Use dynamic programming to determine the production schedule that minimises the costs given above. Complete the working in the table provided in the answer book and state the minimum cost.

(14)

(Total for Question 6 is 14 marks)



5. Anvi makes boats during the winter months. She can make up to five boats each month.

If she builds more than three boats in any one month, she must hire an assistant at a cost of £400 for that month.

In any month in which boats are made, the overhead costs are £60 for each boat made that month.

A maximum of three boats can be held in storage at the end of each month, at a cost of £70 per boat per month.

Boats must be delivered at the end of each month.

The order schedule for boats is

| Month          | November | December | January | February | March |
|----------------|----------|----------|---------|----------|-------|
| Number ordered | 2        | 5        | 6       | 4        | 3     |

There are no boats in storage at the beginning of November.  
Anvi plans to have no boats left in storage after the end of the March delivery.

- (a) Use dynamic programming to determine the production schedule that minimises the costs given above. Complete the working in the table provided in the answer book and state the minimum cost.
- (12)

The assistant asks to work in November, and Anvi agrees.

- (b) Given that more than three boats are now made in November, state the minimum additional cost of producing all the required boats to the schedule shown above.
- (1)

(Total for Question 5 is 13 marks)

# MARK SCHEMES

official mark schemes



| Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Scheme                                                                                                                                                                                                                               | Marks      | AOs         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-------------|
| <b>1(a)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Reduce rows $\begin{bmatrix} 0 & 13 & 2 & 16 \\ 0 & 2 & 13 & 9 \\ 6 & 4 & 0 & 2 \\ 0 & 2 & 5 & 9 \end{bmatrix}$ and then columns $\begin{bmatrix} 0 & 11 & 2 & 14 \\ 0 & 0 & 13 & 7 \\ 6 & 2 & 0 & 0 \\ 0 & 0 & 5 & 7 \end{bmatrix}$ | M1<br>A1   | 2.1<br>1.1b |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Followed by $\begin{bmatrix} 0 & 11 & 0 & 12 \\ 0 & 0 & 11 & 5 \\ 8 & 4 & 0 & 0 \\ 0 & 0 & 3 & 5 \end{bmatrix}$                                                                                                                      | M1<br>A1ft | 2.1<br>1.1b |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | A – 3, B – 1, C – 4, D – 2 or A – 3, B – 2, C – 4, D – 1                                                                                                                                                                             | A1ft       | 2.2a        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                      | (5)        |             |
| <b>(b)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 158                                                                                                                                                                                                                                  | B1         | 1.1b        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                      | (1)        |             |
| <b>(6 marks)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                      |            |             |
| <b>Notes:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                      |            |             |
| <p><b>(a) M1:</b> simplifying the initial matrix by reducing rows and then columns. (Allow up to 2 independent slips).</p> <p><b>A1:</b> CAO</p> <p><b>M1:</b> develop an improved solution – need to see one double covered +e; one uncovered –e; and one single covered unchanged. 3 lines needed to 4 lines needed (lines may be implied). If lines are drawn they must be correct.</p> <p><b>A1ft:</b> CAO following on from row and column reduction final table. (f/t from previous table with no further slips).</p> <p><b>A1ft:</b> correct allocation ft their optimal table (both previous M marks must have been awarded in (a)) (Must be fully written. Do not accept just indicated on zeros on final matrix).</p> <p><b>(b)B1:</b> CAO – solution of original problem</p> |                                                                                                                                                                                                                                      |            |             |

| Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Scheme                                                                                                                                                                                                                                                                                                                                  | Marks                                            | AOs                                            |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|------------------------------------------------|
| 2(a)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Reduce rows $\begin{bmatrix} 0 & 31 & 34 & 19 \\ 0 & 15 & 66 & 19 \end{bmatrix}$ and then columns<br><br>$\begin{bmatrix} 0 & 0 & 0 & 4 \\ 0 & 40 & 27 & 27 \\ 0 & 25 & 5 & 0 \\ 0 & 9 & 37 & 0 \end{bmatrix}$<br><br>followed by $\begin{bmatrix} 5 & 0 & 0 & 9 \\ 0 & 35 & 22 & 27 \\ 0 & 20 & 0 & 0 \\ 0 & 4 & 32 & 0 \end{bmatrix}$ | 1M1<br>1A1ft<br><br><br><br><br><br>2M1<br>2A1ft | 2.1<br>1.1b<br><br><br><br><br><br>2.1<br>1.1b |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | T – 2, H – 1, J – 3, M – 4                                                                                                                                                                                                                                                                                                              | 3A1                                              | 2.2a                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                         | (6)                                              |                                                |
| (b)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | (£)559                                                                                                                                                                                                                                                                                                                                  | 1B1                                              | 1.1b                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                         | (1)                                              |                                                |
| (7 marks)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                         |                                                  |                                                |
| Notes:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                         |                                                  |                                                |
| <p>(a) <b>1B1:</b> CAO</p> <p><b>1M1:</b> simplifying the initial matrix by reducing rows and then columns. Allow no more than a single error in row reduction together with no more than a single error in column reduction. May combine the two stages of converting from maximum to a minimum problem and row reduction which is acceptable.</p> <p><b>1A1ft:</b> CAO following on from their earlier conversion to maximising. If 1B1 awarded, the result of row and column reduction must be as in the main scheme. If 1B0 awarded, then row and column reduction must fit correctly from their attempt to convert to maximisation problem.</p> <p><b>2M1:</b> develops an improved solution – need to see one double covered +e; one uncovered –e; and one single covered unchanged. 3 lines needed to 4 lines needed</p> <p><b>2A1ft:</b> Improved solution following on from their previous table</p> <p><b>3A1:</b> CSO Correct allocation. Must have gained all previous marks in the question.</p> <p>(b) <b>1B1:</b> CAO – solution of original problem (ignore units lack of or incorrect units)</p> |                                                                                                                                                                                                                                                                                                                                         |                                                  |                                                |

**SC:** Minimising

After row reduction  $\begin{bmatrix} 29 & 23 & 0 & 6 \\ 56 & 10 & 0 & 10 \\ 34 & 3 & 0 & 15 \\ 66 & 51 & 0 & 47 \end{bmatrix}$  and then after column reduction  $\begin{bmatrix} 0 & 20 & 0 & 0 \\ 27 & 7 & 0 & 4 \\ 5 & 0 & 0 & 9 \\ 37 & 48 & 0 & 41 \end{bmatrix}$

After augmentation  $\begin{bmatrix} 0 & 20 & 4 & 0 \\ 23 & 3 & 0 & 0 \\ 5 & 0 & 4 & 9 \\ 33 & 44 & 0 & 37 \end{bmatrix}$  or  $\begin{bmatrix} 0 & 24 & 4 & 0 \\ 23 & 7 & 0 & 0 \\ 1 & 0 & 0 & 5 \\ 33 & 48 & 0 & 37 \end{bmatrix}$

Scores B0 M1A0 M1A1(ft)A0 B0 (So 3 marks max)

**1B0:** No Minimisation

**1M1:** simplifying the initial matrix by reducing rows and then columns – all values ‘correct’

**1A0:** Must be maximising.

**2M1:** develops an improved solution – need to see one double covered +e; one uncovered –e; and one single covered unchanged. 3 lines needed to 4 lines needed

**2A1ft:** Improved solution following on from their previous table

**3A0:** CSO

**1B0:** Must be maximising



| Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Scheme                                                                                                                                                                                                                              | Marks      | AOs         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-------------|
| <b>1(a)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Subtracting each entry from a constant value $\geq 35$ to convert from maximisation problem to minimisation                                                                                                                         | M1         | 1.1b        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Add a sufficiently large number ( $> 15$ ) to cells A3 and B4                                                                                                                                                                       | B1         | 1.1b        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | e.g. $\begin{bmatrix} 6 & 15 & 100 & 12 \\ 3 & 5 & 7 & 100 \\ 0 & 3 & 1 & 10 \\ 6 & 4 & 8 & 5 \end{bmatrix}$                                                                                                                        |            |             |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Reduce rows $\begin{bmatrix} 0 & 9 & 94 & 6 \\ 0 & 2 & 4 & 97 \\ 0 & 3 & 1 & 10 \\ 2 & 0 & 4 & 1 \end{bmatrix}$ and then columns $\begin{bmatrix} 0 & 9 & 93 & 5 \\ 0 & 2 & 3 & 96 \\ 0 & 3 & 0 & 9 \\ 2 & 0 & 3 & 0 \end{bmatrix}$ | M1<br>A1ft | 2.1<br>1.1b |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | followed by $\begin{bmatrix} 0 & 7 & 93 & 3 \\ 0 & 0 & 3 & 94 \\ 0 & 1 & 0 & 7 \\ 4 & 0 & 5 & 0 \end{bmatrix}$ or $\begin{bmatrix} 0 & 7 & 91 & 3 \\ 0 & 0 & 1 & 94 \\ 2 & 3 & 0 & 9 \\ 4 & 0 & 3 & 0 \end{bmatrix}$                | M1<br>A1ft | 2.1<br>1.1b |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | A – 1, B – 2, C – 3, D – 4                                                                                                                                                                                                          | B1ft       | 1.1b        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                     | (7)        |             |
| <b>(b)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | £123                                                                                                                                                                                                                                | B1         | 1.1b        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                     | (1)        |             |
| <b>(8 marks)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                     |            |             |
| <b>Notes:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                     |            |             |
| <p><b>(a) M1:</b> convert from maximisation to minimisation (allow at most two errors)</p> <p><b>B1:</b> adding a large number (at least 16) to cells A3 and B4</p> <p><b>M1:</b> simplifying the initial matrix by reducing rows and then columns</p> <p><b>A1ft:</b> cao following on from their earlier subtraction</p> <p><b>M1:</b> develop an improved solution – need to see one double covered +e; one uncovered –e; and one single covered unchanged. 3 lines needed to 4 lines needed</p> <p><b>A1ft:</b> cao following on from row and column reduction final table</p> <p><b>(b) B1ft:</b> correct allocation ft their optimal table (all previous M marks must have been awarded in (a))</p> <p><b>B1:</b> cao – solution of original problem</p> |                                                                                                                                                                                                                                     |            |             |



| Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Scheme                                                                                                                                                                                                                                                                                                                | Marks            | AOs                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------|
| <b>4(a)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Since maximising, subtract all elements from some value $\geq 52$<br>e.g.<br>$\begin{bmatrix} 18 & 32 & 34 & 37 \\ 3 & 21 & 40 & 18 \\ 4 & 25 & 29 & 26 \\ 0 & 7 & 10 & 10 \end{bmatrix}$                                                                                                                             | B1               | 1.1b                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Reduce rows $\begin{bmatrix} 0 & 14 & 16 & 19 \\ 0 & 18 & 37 & 15 \\ 0 & 21 & 25 & 22 \\ 0 & 7 & 10 & 10 \end{bmatrix}$ and then columns $\begin{bmatrix} 0 & 7 & 6 & 9 \\ 0 & 11 & 27 & 5 \\ 0 & 14 & 15 & 12 \\ 0 & 0 & 0 & 0 \end{bmatrix}$                                                                        | M1<br>A1         | 2.1<br>1.1b         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | $\begin{bmatrix} 0 & 2 & 1 & 4 \\ 0 & 6 & 22 & 0 \\ 0 & 9 & 10 & 7 \\ 5 & 0 & 0 & 0 \end{bmatrix}$ followed by $\begin{bmatrix} 0 & 1 & 0 & 3 \\ 1 & 6 & 22 & 0 \\ 0 & 8 & 9 & 6 \\ 6 & 0 & 0 & 0 \end{bmatrix}$ or $\begin{bmatrix} 0 & 1 & 0 & 4 \\ 0 & 5 & 21 & 0 \\ 0 & 8 & 9 & 7 \\ 6 & 0 & 0 & 1 \end{bmatrix}$ | M1<br>A1ft<br>A1 | 2.1<br>1.1b<br>1.1b |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Optimal allocation is A = 3, B = 4, C = 1, D = 2                                                                                                                                                                                                                                                                      | A1ft             | 2.2a                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                       | <b>(7)</b>       |                     |
| <b>(b)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Total score = $18 + 34 + 48 + 45 = 145$                                                                                                                                                                                                                                                                               | B1               | 2.2a                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                       | <b>(1)</b>       |                     |
| <b>(8 marks)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                       |                  |                     |
| <b>Notes:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                       |                  |                     |
| <p><b>(a) B1:</b> converting correctly from a minimisation to maximisation</p> <p><b>M1:</b> simplifying the initial matrix by reducing rows and then columns (allow up to 2 independent slips)</p> <p><b>A1:</b> CAO</p> <p><b>M1:</b> develop an improved solution – need to see one double covered +e; one uncovered –e; and one single covered unchanged. 2 lines needed to 3 lines needed (lines may be implied). If lines are drawn they must be correct.</p> <p><b>A1ft:</b> CAO following on from row and column reduction from previous table (f/t from previous table with no further slips)</p> <p><b>A1:</b> CSO on final table (so must have scored all previous marks)</p> <p><b>A1ft:</b> correct allocation ft their optimal table (both previous M marks must have been awarded in (a)) (Must be fully written. Do not accept just indicated on zeroes on final matrix)</p> <p><b>(b) B1:</b> CAO – solution of original problem (both previous M marks must have been awarded)</p> |                                                                                                                                                                                                                                                                                                                       |                  |                     |

| Question                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Scheme                                                                                                                                                                                                                                   | Marks          | AOs |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----|
| <b>4(a)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Special Case – minimisation – max 4/8                                                                                                                                                                                                    | B0             |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Reduce rows $\begin{bmatrix} 19 & 5 & 3 & 0 \\ 37 & 19 & 0 & 22 \\ 25 & 4 & 0 & 3 \\ 10 & 3 & 0 & 0 \end{bmatrix}$ and then columns $\begin{bmatrix} 9 & 2 & 3 & 0 \\ 27 & 16 & 0 & 22 \\ 15 & 1 & 0 & 3 \\ 0 & 0 & 0 & 0 \end{bmatrix}$ | M1<br>A1       |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | followed by $\begin{bmatrix} 8 & 1 & 3 & 0 \\ 26 & 15 & 0 & 22 \\ 14 & 0 & 0 & 3 \\ 0 & 0 & 1 & 1 \end{bmatrix}$ or $\begin{bmatrix} 9 & 2 & 4 & 0 \\ 26 & 15 & 0 & 21 \\ 14 & 0 & 0 & 2 \\ 0 & 0 & 1 & 0 \end{bmatrix}$                 | M1<br>A1<br>A0 |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Optimal allocation is                                                                                                                                                                                                                    | A0             |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                          | <b>(7)</b>     |     |
| <b>(b)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Total score                                                                                                                                                                                                                              | B0             |     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                          | <b>(1)</b>     |     |
| <b>(8 marks)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                          |                |     |
| <b>Notes:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                          |                |     |
| <p><b>(a) B0:</b> no conversion</p> <p><b>M1:</b> simplifying the initial matrix by reducing rows and then columns (allow up to 2 independent slips)</p> <p><b>A1:</b> CAO</p> <p><b>M1:</b> develop an improved solution – need to see one double covered +e; one uncovered –e; and one single covered unchanged. 3 lines needed to 4 lines needed (lines may be implied). If lines are drawn they must be correct.</p> <p><b>A1:</b> CAO No further marks awarded</p> |                                                                                                                                                                                                                                          |                |     |

| Question                                             | Scheme                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Marks | AOs    |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------|--------|--------------|-------|---|---|----|---|----|--|---|----|---|----|--|---|----|---|----|---|---|----|---|------------|--|--|----|---|------------|--|--|----|---|------------|--|---|----|---|-----------|--|--|----|---|------------|---|---|----|---|-------------|--|--|----|---|-------------|--|---|----|---|------------|--|--|----|---|------------|--|---|----|---|------------|---|---|----|---|-------------|--|--|----|---|-------------|--|---|----|---|-------------|--|--|----|---|------------|--|--|----|---|-------------|---|---|----|---|-------------|--|--|----|---|--------------|----|------|
| 6(a)                                                 | <table><tr><th>Stage</th><th>State</th><th>Action</th><th>Dest</th><th>Value</th></tr><tr><td>1</td><td>H</td><td>HT</td><td>T</td><td>2*</td></tr><tr><td></td><td>I</td><td>IT</td><td>T</td><td>3*</td></tr><tr><td></td><td>J</td><td>JT</td><td>T</td><td>4*</td></tr><tr><td>2</td><td>F</td><td>FH</td><td>H</td><td>5 + 2 = 7*</td></tr><tr><td></td><td></td><td>FI</td><td>I</td><td>4 + 3 = 7*</td></tr><tr><td></td><td></td><td>FJ</td><td>J</td><td>6 + 4 = 10</td></tr><tr><td></td><td>G</td><td>GH</td><td>H</td><td>5 + 2 = 7</td></tr><tr><td></td><td></td><td>GI</td><td>I</td><td>3 + 3 = 6*</td></tr><tr><td>3</td><td>C</td><td>CF</td><td>F</td><td>3 + 7 = 10*</td></tr><tr><td></td><td></td><td>CG</td><td>G</td><td>4 + 6 = 10*</td></tr><tr><td></td><td>D</td><td>DF</td><td>F</td><td>3 + 7 = 10</td></tr><tr><td></td><td></td><td>DG</td><td>G</td><td>1 + 6 = 7*</td></tr><tr><td></td><td>E</td><td>EG</td><td>G</td><td>2 + 6 = 8*</td></tr><tr><td>4</td><td>A</td><td>AC</td><td>C</td><td>4 + 10 = 14</td></tr><tr><td></td><td></td><td>AE</td><td>E</td><td>5 + 8 = 13*</td></tr><tr><td></td><td>B</td><td>BC</td><td>C</td><td>4 + 10 = 14</td></tr><tr><td></td><td></td><td>BD</td><td>D</td><td>7 + 7 = 14</td></tr><tr><td></td><td></td><td>BE</td><td>E</td><td>4 + 8 = 12*</td></tr><tr><td>5</td><td>S</td><td>SA</td><td>A</td><td>3 + 13 = 16</td></tr><tr><td></td><td></td><td>SB</td><td>B</td><td>2 + 12 = 14*</td></tr></table> | Stage | State  | Action | Dest         | Value | 1 | H | HT | T | 2* |  | I | IT | T | 3* |  | J | JT | T | 4* | 2 | F | FH | H | 5 + 2 = 7* |  |  | FI | I | 4 + 3 = 7* |  |  | FJ | J | 6 + 4 = 10 |  | G | GH | H | 5 + 2 = 7 |  |  | GI | I | 3 + 3 = 6* | 3 | C | CF | F | 3 + 7 = 10* |  |  | CG | G | 4 + 6 = 10* |  | D | DF | F | 3 + 7 = 10 |  |  | DG | G | 1 + 6 = 7* |  | E | EG | G | 2 + 6 = 8* | 4 | A | AC | C | 4 + 10 = 14 |  |  | AE | E | 5 + 8 = 13* |  | B | BC | C | 4 + 10 = 14 |  |  | BD | D | 7 + 7 = 14 |  |  | BE | E | 4 + 8 = 12* | 5 | S | SA | A | 3 + 13 = 16 |  |  | SB | B | 2 + 12 = 14* | B1 | 3.1a |
|                                                      | Stage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | State | Action | Dest   | Value        |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | H     | HT     | T      | 2*           |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
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|                                                      | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | F     | FH     | H      | 5 + 2 = 7*   |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
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|                                                      | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | C     | CF     | F      | 3 + 7 = 10*  |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
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|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | E     | EG     | G      | 2 + 6 = 8*   |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | A     | AC     | C      | 4 + 10 = 14  |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       | AE     | E      | 5 + 8 = 13*  |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | B     | BC     | C      | 4 + 10 = 14  |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       | BD     | D      | 7 + 7 = 14   |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       | BE     | E      | 4 + 8 = 12*  |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | 5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | S     | SA     | A      | 3 + 13 = 16  |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       | SB     | B      | 2 + 12 = 14* |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | M1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 3.1a  |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | A1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1.1b  |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | M1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1.1b  |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | A1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1.1b  |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      | M1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1.1b  |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| A1ft                                                 | 1.1b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| A1                                                   | 1.1b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| A1                                                   | 3.2a                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| (9)                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| Latest time that Elena can start her journey is 7 am |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| (b)                                                  | Route: SBEGIT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | B1    | 2.2a   |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | (1)   |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |
| (10 marks)                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       |        |        |              |       |   |   |    |   |    |  |   |    |   |    |  |   |    |   |    |   |   |    |   |            |  |  |    |   |            |  |  |    |   |            |  |   |    |   |           |  |  |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |            |  |  |    |   |            |  |   |    |   |            |   |   |    |   |             |  |  |    |   |             |  |   |    |   |             |  |  |    |   |            |  |  |    |   |             |   |   |    |   |             |  |  |    |   |              |    |      |

## Notes for Question 6

**All M marks – must bring earlier optimal results into calculations. Ignore extra rows. Penalise lack of \* only once per question.**

**B1:** CAO for first stage

**M1:** Second stage completed. At least 4 rows, something in each cell.

**A1:** CAO for second stage exactly 5 rows

**M1:** Third stage completed. At least 4 rows, something in each cell.

**A1:** CAO for third stage exactly 5 rows

**M1:** Fourth stage completed. 5 rows, something in each cell.

**A1ft:** correct ft their optimal values from third stage

**A1:** CAO for fifth stage

**A1:** Correct latest start time in context (e.g. 7 am, 07:00, etc.)

**(b)**

**B1:** Correct route (dependent on all previous M marks)

Special Case – Maximin or Minimax

| Stage | State | Action | Dest | Value           | Value           |
|-------|-------|--------|------|-----------------|-----------------|
| 1     | H     | HT     | T    | 2*              | 2*              |
|       | I     | IT     | T    | 3*              | 3*              |
|       | J     | JT     | T    | 4*              | 4*              |
| 2     | F     | FH     | H    | Min (5, 2) = 2  | Max (5, 2) = 5  |
|       |       | FI     | I    | Min (4, 3) = 3  | Max (4, 3) = 4* |
|       |       | FJ     | J    | Min (6, 4) = 4* | Max (6, 4) = 6  |
|       | G     | GH     | H    | Min (5, 2) = 2  | Max (5, 2) = 5* |
|       |       | GI     | I    | Min (3, 3) = 3* | Max (3, 3) = 3  |
| 3     | C     | CF     | F    | Min (3, 4) = 3* | Max (3, 4) = 4* |
|       |       | CG     | G    | Min (4, 3) = 3* | Max (4, 5) = 5  |
|       | D     | DF     | F    | Min (3, 4) = 3* | Max (3, 4) = 4* |
|       |       | DG     | G    | Min (1, 3) = 1  | Max (1, 5) = 5  |
|       | E     | EG     | G    | Min (2, 3) = 2* | Max (2, 5) = 5* |
| 4     | A     | AC     | C    | Min (4, 3) = 3* | Max (4, 4) = 4* |
|       |       | AE     | E    | Min (5, 2) = 2  | Max (5, 5) = 5  |
|       | B     | BC     | C    | Min (4, 3) = 3* | Max (4, 4) = 4* |
|       |       | BD     | D    | Min (7, 3) = 3* | Max (7, 4) = 7  |
|       |       | BE     | E    | Min (4, 2) = 2  | Max (4, 5) = 5  |
| 5     | S     | SA     | A    | Min (3, 3) = 3* | Max (3, 4) = 4* |
|       |       | SB     | B    | Min (2, 3) = 2  | Max (2, 4) = 4* |

B1 M1 A0 M1 A0 M1 A0 A0 A0 B0 - Max 4/10





**Notes:****(a) B1:** cao**Throughout (b):**

- Condone lack of destination column and/or reversed stage numbers throughout
- Only penalise incorrect result in value – ie ignore working values
- Penalise absence of state or action column with first two A marks earned only
- Penalise empty/errors in stage column with first A mark earned only
- If maximin, minimum, maximum, etc. then only the B mark and M marks can be awarded in (b) (so 4 out of 9 maximum) and one B mark can be awarded in (c) following through a correct route from their table

**M marks in (b) - must bring earlier optimal results into calculations at least once****(b)****B1:** Stage 1 correct**M1:** Stage 2 completed with 4 states and at least 9 rows. Bod if something in each cell**A1:** Any two states in Stage 2 correct**A1:** cao all 4 states correct in Stage 2 (no extra rows)**M1:** Stage 3 completed with 3 states and at least 8 rows. Bod if something in each cell**A1ft:** cao any 2 states correct in Stage 3 on the follow through**A1:** cao all 3 states in Stage 3 (no extra rows)**M1:** Stage 4 completed with 1 state and at least 3 rows. Bod if something in each cell**A1ft:** cao for Stage 4 following through their \* values (no extra rows)**(c)****B1ft:** One correct route (dependent on first B mark and all M marks in (b)) following through their least values (oe) at each stage in (b)**B1:** Both routes correct (dependent on first B mark and all M marks in (b))

| Question   | Scheme                                                                 |       |        |       |                 | Marks          | AOs                  |
|------------|------------------------------------------------------------------------|-------|--------|-------|-----------------|----------------|----------------------|
| 7(a)       | Stage                                                                  | State | Action | Dest. | Value           | B1             | 3.1a                 |
|            | Trainers                                                               | 0     | 0      | 0     | 0               |                |                      |
|            |                                                                        | 1     | 1      | 0     | 50              |                |                      |
|            |                                                                        | 2     | 2      | 0     | 90              |                |                      |
|            |                                                                        | 3     | 3      | 0     | 170             |                |                      |
|            |                                                                        | 4     | 4      | 0     | 225             |                |                      |
|            |                                                                        | 5     | 5      | 0     | 295             |                |                      |
|            | Sandals                                                                | 0     | 0      | 0     | 0               |                |                      |
|            |                                                                        | 1     | 1      | 0     | 70 + 0 = 70*    |                |                      |
|            |                                                                        |       | 0      | 1     | 0 + 50 = 50     |                |                      |
|            |                                                                        | 2     | 2      | 0     | 110 + 0 = 110   | M1<br>A1<br>A1 | 3.1a<br>1.1b<br>1.1b |
|            |                                                                        |       | 1      | 1     | 70 + 50 = 120*  |                |                      |
|            |                                                                        |       | 0      | 2     | 0 + 90 = 90     |                |                      |
|            |                                                                        | 3     | 3      | 0     | 165 + 0 = 165   |                |                      |
|            |                                                                        |       | 2      | 1     | 110 + 50 = 160  |                |                      |
|            |                                                                        |       | 1      | 2     | 70 + 90 = 160   |                |                      |
|            |                                                                        |       | 0      | 3     | 0 + 170 = 170*  |                |                      |
|            |                                                                        | 4     | 4      | 0     | 245 + 0 = 245*  |                |                      |
|            |                                                                        |       | 3      | 1     | 165 + 50 = 215  |                |                      |
|            |                                                                        |       | 2      | 2     | 110 + 90 = 200  |                |                      |
|            |                                                                        |       | 1      | 3     | 70 + 170 = 240  | M1<br>A1<br>A1 | 1.1b<br>1.1b<br>1.1b |
|            |                                                                        |       | 0      | 4     | 0 + 225 = 225   |                |                      |
|            |                                                                        | 5     | 5      | 0     | 300 + 0 = 300*  |                |                      |
|            |                                                                        |       | 4      | 1     | 245 + 50 = 295  |                |                      |
|            |                                                                        |       | 3      | 2     | 165 + 90 = 255  |                |                      |
|            |                                                                        |       | 2      | 3     | 110 + 170 = 280 |                |                      |
|            |                                                                        |       | 1      | 4     | 70 + 225 = 295  |                |                      |
|            |                                                                        |       | 0      | 5     | 0 + 295 = 295   |                |                      |
|            | High                                                                   | 5     | 5      | 0     | 305 + 0 = 305   |                |                      |
|            | heels                                                                  |       | 4      | 1     | 235 + 70 = 305  |                |                      |
|            |                                                                        |       | 3      | 2     | x + 120         | M1<br>A1ft     | 1.1b<br>1.1b         |
|            |                                                                        |       | 2      | 3     | 115 + 170 = 285 |                |                      |
|            |                                                                        |       | 1      | 4     | 75 + 245 = 320  |                |                      |
|            |                                                                        |       | 0      | 5     | 0 + 300 = 300   |                |                      |
|            |                                                                        |       |        |       |                 |                |                      |
|            | 320 and x +120                                                         |       |        |       |                 | A1ft           | 1.1b                 |
|            |                                                                        |       |        |       |                 | (10)           |                      |
| (b)        | Trainers: 0                  Sandals: 4                  High heels: 1 |       |        |       |                 | B1             | 1.1b                 |
|            | Trainers: 1                  Sandals: 1                  High heels: 3 |       |        |       |                 | B1             | 2.2a                 |
|            |                                                                        |       |        |       |                 | (2)            |                      |
| (12 marks) |                                                                        |       |        |       |                 |                |                      |

**Notes:**

- (a) B1:** CAO for the first stage (all six rows) – entries in all columns must be correct – candidates may start with state 5 (rather than state 0) which is fine
- M1:** Second stage – my states 1, 2 and 3 (so at least 9 rows in the first half of the second stage or at least 20 non-zero rows). Value column must be complete with at least one value correct for each state – ignore entries in all other columns
- A1:** Value column for states 1, 2 and 3 correct for the second stage – ignore entries in all other columns and condone additional rows
- A1:** CAO for states 0, 1, 2 and 3 of the second stage (no additional rows for these four states) – entries in all columns must be correct
- M1:** Second stage – my states 4 and 5 (so at least 11 rows in the second half of the second stage or at least 20 non-zero rows). Value column must be complete with at least one value correct for each state – ignore entries in all other columns
- A1:** Value column for states 4 and 5 correct for the second stage – ignore entries in all other columns and condone additional rows
- A1:** CAO for states 4 and 5 of the second stage (no additional rows for these two states) - entries in all columns must be correct
- M1:** At least 6 rows for the third stage. Value column must be complete with at least 3 values correct – ignore entries in all other columns
- A1ft:** CAO for third stage correct (no additional rows for this stage) - entries in all columns must be correct
- A1ft:** Must have earned all previous M marks from their completed dynamic programming but ft their result
- (b) B1:** One correct allocation (dependent on first three M marks in (a))
- B1:** For both correct (dependent on first three M marks in (a))

| Question                                                                                                                                                                                                                                                              | Scheme                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Marks  | AOs            |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|----------------|--------------------|-------------|-------|---|---|----|---|-----|---|----|---|-----|---|----|---|------|---|----|---|-----|---|---|----|---|------------------|----|---|----------------|---|----|---|----------------|----|---|----------------|---|----|---|----------------|----|---|-----------------|----|---|--------------------|---|---|----|---|---------------|----|---|----------------|---|----|---|---------------|----|---|---------------|----|---|--------------------|---|----|---|----------------|---|---|----|---|----------------|----|---|----------|----|---|---------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| 3(a)                                                                                                                                                                                                                                                                  | Dijkstra's algorithm cannot be used on a network with negative weights                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1B1    | 3.5b           |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | (1)    |                |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| (b)(i)                                                                                                                                                                                                                                                                | <table><tr><th>Stage</th><th>State</th><th>Action</th><th>Destination</th><th>Value</th></tr><tr><td rowspan="4">0</td><td>G</td><td>GT</td><td>T</td><td>28*</td></tr><tr><td>H</td><td>HT</td><td>T</td><td>19*</td></tr><tr><td>I</td><td>IT</td><td>T</td><td>-24*</td></tr><tr><td>J</td><td>JT</td><td>T</td><td>17*</td></tr><tr><td rowspan="7">1</td><td rowspan="2">D</td><td>DG</td><td>G</td><td><math>-24 + 28 = 4 *</math></td></tr><tr><td>DH</td><td>H</td><td><math>18 + 19 = 37</math></td></tr><tr><td rowspan="2">E</td><td>EH</td><td>H</td><td><math>24 + 19 = 43</math></td></tr><tr><td>EI</td><td>I</td><td><math>27 - 24 = 3*</math></td></tr><tr><td rowspan="3">F</td><td>FG</td><td>G</td><td><math>-25 + 28 = 3</math></td></tr><tr><td>FI</td><td>I</td><td><math>14 - 24 = -10</math></td></tr><tr><td>FJ</td><td>J</td><td><math>-30 + 17 = -13 *</math></td></tr><tr><td rowspan="5">2</td><td rowspan="2">A</td><td>AD</td><td>D</td><td><math>32 + 4 = 36</math></td></tr><tr><td>AE</td><td>E</td><td><math>29 + 3 = 32*</math></td></tr><tr><td rowspan="3">B</td><td>BD</td><td>D</td><td><math>20 + 4 = 24</math></td></tr><tr><td>BE</td><td>E</td><td><math>19 + 3 = 22</math></td></tr><tr><td>BF</td><td>F</td><td><math>-17 - 13 = -30 *</math></td></tr><tr><td>C</td><td>CF</td><td>F</td><td><math>13 - 13 = 0*</math></td></tr><tr><td rowspan="3">3</td><td rowspan="3">S</td><td>SA</td><td>A</td><td><math>13 + 32 = 45</math></td></tr><tr><td>SB</td><td>B</td><td><math>x - 30</math></td></tr><tr><td>SC</td><td>C</td><td><math>24 + 0 = 24</math></td></tr></table> <p><math>x - 30 &lt; 24</math><br/><math>(0 \leq) x &lt; 54</math></p> | Stage  | State          | Action             | Destination | Value | 0 | G | GT | T | 28* | H | HT | T | 19* | I | IT | T | -24* | J | JT | T | 17* | 1 | D | DG | G | $-24 + 28 = 4 *$ | DH | H | $18 + 19 = 37$ | E | EH | H | $24 + 19 = 43$ | EI | I | $27 - 24 = 3*$ | F | FG | G | $-25 + 28 = 3$ | FI | I | $14 - 24 = -10$ | FJ | J | $-30 + 17 = -13 *$ | 2 | A | AD | D | $32 + 4 = 36$ | AE | E | $29 + 3 = 32*$ | B | BD | D | $20 + 4 = 24$ | BE | E | $19 + 3 = 22$ | BF | F | $-17 - 13 = -30 *$ | C | CF | F | $13 - 13 = 0*$ | 3 | S | SA | A | $13 + 32 = 45$ | SB | B | $x - 30$ | SC | C | $24 + 0 = 24$ | 1B1<br><br>1M1<br>1A1<br>2A1<br><br>2M1<br>3A1ft<br>4A1<br><br>3M1<br>5A1ft<br><br>4dM1<br>6A1 | 3.1a<br><br>3.1a<br>1.1b<br>1.1b<br><br>1.1b<br>1.1b<br>1.1b<br><br>1.1b<br>1.1b<br><br>3.1a<br>2.2a |
| Stage                                                                                                                                                                                                                                                                 | State                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Action | Destination    | Value              |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| 0                                                                                                                                                                                                                                                                     | G                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | GT     | T              | 28*                |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       | H                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | HT     | T              | 19*                |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       | I                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | IT     | T              | -24*               |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       | J                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | JT     | T              | 17*                |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| 1                                                                                                                                                                                                                                                                     | D                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | DG     | G              | $-24 + 28 = 4 *$   |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
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|                                                                                                                                                                                                                                                                       | E                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | EH     | H              | $24 + 19 = 43$     |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
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|                                                                                                                                                                                                                                                                       | F                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | FG     | G              | $-25 + 28 = 3$     |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
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| 2                                                                                                                                                                                                                                                                     | A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | AD     | D              | $32 + 4 = 36$      |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
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|                                                                                                                                                                                                                                                                       | B                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | BD     | D              | $20 + 4 = 24$      |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
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| C                                                                                                                                                                                                                                                                     | CF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | F      | $13 - 13 = 0*$ |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| 3                                                                                                                                                                                                                                                                     | S                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | SA     | A              | $13 + 32 = 45$     |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | SB     | B              | $x - 30$           |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | SC     | C              | $24 + 0 = 24$      |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| (ii)                                                                                                                                                                                                                                                                  | Route: S – B – F – J – T                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 1B1    | 2.2a           |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
|                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | (12)   |                |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| (13 marks)                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |                |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| Notes:                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |                |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |
| (a) 1B1: CAO – Do not accept ‘Dijkstra’s cannot be used on a directed network’<br>Condone any reference to negative (weights) or ‘negative edges’. Also condone ‘cannot be used with positive and negative arcs.’ But NOT answers which include incorrect statements. |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |        |                |                    |             |       |   |   |    |   |     |   |    |   |     |   |    |   |      |   |    |   |     |   |   |    |   |                  |    |   |                |   |    |   |                |    |   |                |   |    |   |                |    |   |                 |    |   |                    |   |   |    |   |               |    |   |                |   |    |   |               |    |   |               |    |   |                    |   |    |   |                |   |   |    |   |                |    |   |          |    |   |               |                                                                                                |                                                                                                      |

**Throughout (b):**

- **Condone lack of destination column and/or reversed stage numbers throughout**
- **Only penalise incorrect result in value – ie ignore working values**
- **Penalise absence of state or action column with first two A marks earned only**
- **Penalise empty/errors in stage column with first A mark earned only**
- **Penalise occurrence of single errors in state/action/destination with the relevant A mark - once only.**
- **Interchanged state and destination columns penalise with first two A marks**

**M marks - must bring earlier optimal results into calculations at least once per stage**

**1B1:** Stage 0 correct

**1M1:** Stage 1 completed with 3 states and at least 7 rows. Bod if something in each cell

**1A1:** any two states in Stage 1 correct

**2A1:** CAO all 3 states correct in Stage 1 (must be 7 rows and no extra rows)

**2M1:** Stage 2 completed with 3 states and at least 6 rows. Bod if something in each cell

**3A1ft:** CAO any 2 states correct in Stage 2 on the follow through

**4A1:** CAO all 3 states in Stage 1 (no extra rows)

**3M1:** Stage 3 completed with 1 state and at least 3 rows. Bod if something in each cell

**5A1ft:** CAO for Stage 3 following through their optimal values (no extra rows)

**4dM1:** Dependent on scoring 3rd method mark and at least one of the first two method marks. Award for forming a correct inequality using their SB and the least of their SA and their SC. Allow  $\leq$  for this mark. Must follow from stage 3 in their table. So M0 if no  $x$  appears in stage 3. This M mark could be implied, however by ' $x < 54$ ' if stage 3 is correct.

**6A1:** CSO correct deduction of range of possible values of  $x$ . Strict inequality required for this mark.

**1dB1:** Correct route. Dependent on 3<sup>rd</sup> method mark.

**SC in part b:**

Minimax/Maximin approach

Could score a maximum of B1 M1A0A0 M1A0A0 M1A0 M0A0 (max 4 marks) for the following:

**1M1:** Stage 1 completed with 3 states and at least 7 rows. Bod if something in each cell

**2M1:** Stage 2 completed with 3 states and at least 6 rows. Bod if something in each cell

**3M1:** Stage 3 completed with 1 state and at least 3 rows. Bod if something in each cell

**NB must bring earlier optimal results into calculations at least once per stage for each M mark.**



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**Notes:**

- Condone lack of destination column
- Only penalise incorrect result in value – i.e. ignore working values
- Penalise absence of state or action column with first two A marks earned only
- Penalise empty/errors in stage column with first A mark earned only

**For all M marks – must bring optimal results from previous stage into calculation at least once – so from Stage 1 if neither of their 40 or their 41 are used in Stage 2 then M0. Ignore extra rows. Must have correct ingredients (appearance fee, cost) at least once per stage. If no working seen then values in the Value column must be correct to imply these marks. Penalise lack of \* only once per question.**

B1: CAO (Stage 1)

M1: Second stage completed. At least six rows. Bod if something in each cell

A1: Any one state correct with no extra rows for this state

A1: Both states correct with no extra rows for Stage 2

M1: Third stage completed. At least six rows. Bod if something in each cell

A1ft: Any two states correct – ft their optimal values from Stage 2 (no extra rows)

A1: All three states correct for Stage 3 (no extra rows)

M1: Fourth stage completed. At least six rows. Bod if something in each column

A1ft: Any one state correct - ft their optimal values from Stage 3 (no extra rows)

A1: Both states correct (no extra rows)

A1: Final state correct (no extra rows)

B1: Correct route (dependent on all previous M marks earned). (start and/or finish at S may not be stated)

B1: CAO (dependent on all previous M marks earned) – units not required – but not for 161



| Question        | Scheme                                             |       |        |       |                        | Marks | AOs  |    |
|-----------------|----------------------------------------------------|-------|--------|-------|------------------------|-------|------|----|
| 6               | Alternative with values added at subsequent Stage. |       |        |       |                        | B1    | 3.1a |    |
|                 |                                                    |       |        |       |                        |       |      |    |
|                 | Stage                                              | State | Action | Dest. | Value                  |       |      |    |
|                 | 1                                                  | H     | HS     | S     | $-7 = -7^*$            |       |      |    |
|                 |                                                    | I     | IS     | S     | $-8 = -8^*$            |       |      |    |
|                 |                                                    | J     | JS     | S     | $-8 = -8^*$            |       |      |    |
|                 | 2                                                  | F     | FH     | H     | $47 - 6 - 7 = 34^*$    |       |      |    |
|                 |                                                    |       | FI     | I     | $49 - 7 - 8 = 34^*$    |       |      |    |
|                 |                                                    |       | FJ     | J     | $48 - 8 - 8 = 32$      |       |      | M1 |
|                 |                                                    | G     | GH     | H     | $47 - 7 - 7 = 33$      | A1    |      |    |
|                 |                                                    |       | GI     | I     | $49 - 8 - 8 = 33$      | A1    |      |    |
|                 |                                                    |       | GJ     | J     | $48 - 6 - 8 = 34^*$    |       |      |    |
|                 | 3                                                  | C     | CF     | F     | $44 - 7 + 34 = 71$     |       |      |    |
|                 |                                                    |       | CG     | G     | $45 - 5 + 34 = 74^*$   |       |      |    |
|                 |                                                    | D     | DF     | F     | $44 - 6 + 34 = 72^*$   | M1    |      |    |
|                 |                                                    |       | DG     | G     | $45 - 7 + 34 = 72^*$   | A1ft  |      |    |
|                 |                                                    | E     | EF     | F     | $44 - 7 + 34 = 71$     | A1    |      |    |
|                 |                                                    |       | EG     | G     | $45 - 6 + 34 = 73^*$   |       |      |    |
|                 | 4                                                  | A     | AC     | C     | $48 - 3 + 74 = 119^*$  |       |      |    |
|                 |                                                    |       | AD     | D     | $47 - 4 + 72 = 115$    |       |      |    |
|                 |                                                    |       | AE     | E     | $49 - 5 + 73 = 117$    | M1    |      |    |
|                 |                                                    | B     | BC     | C     | $48 - 5 + 74 = 117^*$  | A1ft  |      |    |
|                 |                                                    |       | BD     | D     | $47 - 4 + 72 = 115$    | A1    |      |    |
|                 |                                                    |       | BE     | E     | $49 - 6 + 73 = 116$    |       |      |    |
|                 | 5                                                  | S     | SA     | A     | $47 - 5 + 119 = 161^*$ |       |      |    |
|                 |                                                    |       | SB     | B     | $45 - 2 + 117 = 160$   | A1    |      |    |
|                 | Optimal schedule is SACGJS                         |       |        |       |                        | B1    | 2.2a |    |
|                 | Optimal expected income (£) 16 100                 |       |        |       |                        | B1    | 3.2a |    |
| Notes: as above |                                                    |       |        |       |                        |       |      |    |



Special Case – ignore stars throughout

**B1:** CAO (Stage 1)

**M1:** Second stage completed. At least six rows. Bod if something in each cell

**A1:** Both states correct with no extra rows for Stage 2 then **A0**

**M1:** Third stage completed. At least six rows. Bod if something in each cell

**A1:** Two out of three states with all values correct (no follow through) Then **A0**

**M1:** Fourth stage completed. At least six rows. Bod if something in each column. No further marks can be awarded



| Qu | Scheme                 |         |          |       |                              | Marks          | AOs                  |
|----|------------------------|---------|----------|-------|------------------------------|----------------|----------------------|
| 6  |                        |         |          |       |                              | M1<br>A1<br>A1 | 3.1a<br>1.1b<br>1.1b |
|    | Stage                  | State   | Action   | Dest  | Value                        |                |                      |
|    | May                    | 2       | 0        | 0     | 160 = 160*                   |                |                      |
|    | (2)                    | 1       | 1        | 0     | 80 + 35 = 115*               |                |                      |
|    |                        | 0       | 2        | 0     | 70 = 70*                     |                |                      |
|    | April                  | 3       | 2        | 0     | 240 + 70 + 70 = 380*         |                |                      |
|    | (5)                    |         | 3        | 1     | 240 + 105 + 250 + 115 = 710  |                |                      |
|    |                        |         | 4        | 2     | 240 + 140 + 250 + 160= 790   |                |                      |
|    |                        | 2       | 3        | 0     | 160 + 105 + 250 + 70 = 585*  |                |                      |
|    |                        |         | 4        | 1     | 160 + 140 + 250 + 115 = 665  |                |                      |
|    |                        | 1       | 4        | 0     | 80 + 140 + 250 + 70= 540*    |                |                      |
|    | March                  | 3       | 1        | 1     | 240 + 35 + 540= 815*         |                |                      |
|    | (3)                    |         | 2        | 2     | 240 + 70 + 585 = 895         |                |                      |
|    |                        |         | 3        | 3     | 240 + 105 + 250 + 380= 975   |                |                      |
|    |                        | 2       | 2        | 1     | 160 + 70 + 540= 770*         |                |                      |
|    |                        |         | 3        | 2     | 160 + 105 + 250 + 585= 1100  |                |                      |
|    |                        |         | 4        | 3     | 160 + 140 + 250 + 380 = 930  |                |                      |
|    |                        | 1       | 3        | 1     | 80 + 105 + 250 + 540 = 975*  |                |                      |
|    |                        |         | 4        | 2     | 80+ 140 + 250 + 585= 1055    |                |                      |
|    |                        | 0       | 4        | 1     | 140 + 250 + 540 = 930*       |                |                      |
|    | Feb                    | 3       | 0        | 0     | 240 + 930 = 1170             |                |                      |
|    | (3)                    |         | 1        | 1     | 240 + 35 + 975= 1250         |                |                      |
|    |                        |         | 2        | 2     | 240 + 70 + 770 = 1080*       |                |                      |
|    |                        |         | 3        | 3     | 240 + 105 + 250 + 815 = 1410 |                |                      |
|    |                        | 2       | 1        | 0     | 160 + 35 + 930= 1125*        |                |                      |
|    |                        |         | 2        | 1     | 160 + 70+ 975= 1205          |                |                      |
|    |                        |         | 3        | 2     | 160 + 105 + 250 + 770 = 1285 |                |                      |
|    |                        |         | 4        | 3     | 160 + 140 + 250 + 815 = 1365 |                |                      |
|    |                        | 1       | 2        | 0     | 80+ 70+ 930= 1080*           |                |                      |
|    |                        |         | 3        | 1     | 80 + 105 + 250 + 975 = 1410  |                |                      |
|    |                        |         | 4        | 2     | 80 + 140 + 250 + 770 = 1240  |                |                      |
|    |                        | 0       | 3        | 0     | 105 + 250 + 930 = 1285*      |                |                      |
|    |                        |         | 4        | 1     | 140 + 250 + 975 = 1365       |                |                      |
|    | Jan                    | 0       | 1        | 0     | 35 + 1285 = 1320             |                |                      |
|    | (1)                    |         | 2        | 1     | 70 + 1080= 1150*             |                |                      |
|    |                        |         | 3        | 2     | 105 + 250 + 1125= 1480       |                |                      |
|    |                        |         | 4        | 3     | 140 + 250 + 1080 = 1470      |                |                      |
|    |                        |         |          |       |                              | B1<br><br>B1   | 2.2a<br><br>1.1b     |
|    | Month                  | January | February | March | April                        |                |                      |
|    | Number made            | 2       | 2        | 4     | 4                            | 2              |                      |
|    | Minimum Cost: (£) 1150 |         |          |       |                              | (14 marks)     |                      |



**Notes:**

**All M marks – must bring earlier optimal results into calculations. Ignore extra rows. Must have right ‘ingredients’ (storage costs, overhead costs and additional workers) at least once per stage. Ingredients may be summed into a single figure. Correct total figure implies correct calculation. Penalise lack of \* only once per question.**

**M1:** Second stage completed. 6 rows, something in each cell.

**A1:** Any two states correct

**A1:** CAO for second stage

**M1:** Third stage completed. 9 rows with correct state, action and destination. Something in each cell. Condone at least 8 rows, with correct state, action and destination.

**A1ft:** Any two states correct – ft their optimal values

**A1:** CAO for third stage

**M1:** Fourth stage completed. 13 rows, with correct state, action and destination. Something in each cell. Condone at least 11 rows, with correct state, action and destination.

**A1ft:** Any two states correct – ft their optimal values

**A1ft:** Any three states correct – ft their optimal values

**A1:** CAO for fourth stage

**M1:** Fifth stage completed. 4 rows, something in each cell.

**A1:** CAO for fifth stage

**B1:** Correct allocation (dependent on all previous M marks)

**B1:** Correct minimum cost (dependent on all previous M marks)



| Ques<br>tion | Scheme |       |        |      |       | Marks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | AOs |
|--------------|--------|-------|--------|------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------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| 5(a)         | Stage  | State | Action | Dest | Value | M1<br>A1<br>A1<br>A1<br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br>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|     |



(13 marks)

## Notes for Question 5

**All M marks – must bring earlier optimal results into calculations. Ignore extra rows. Must have right ‘ingredients’ (storage costs, overhead costs and workers) at least once per stage. Penalise lack of \* only once per question. Additional rows which are not rejected are penalised by the loss of the final A mark in each stage**

(a)

**M1:** Second stage completed. At least 9 rows, something in each cell. Condone extra rows

**A1:** Any one state correct

**A1:** All four states complete (13 rows) with any two states correct

**A1:** CAO for second stage no extra rows

**M1:** Third stage completed. 6 rows, something in each cell. Condone extra rows

**A1ft:** Any one state correct – ft their optimal values

**A1:** CAO for third stage no extra rows

**M1:** Fourth stage completed. 6 rows, something in each cell. Condone extra rows

**A1ft:** Correct fourth stage – ft their optimal values

**A1:** CSO all stages

**B1:** Correct allocation (dependent on all previous M marks)

**B1:** Correct minimum cost (dependent on all previous M marks)

(b)

**B1:** CAO (dependent on all M marks in (a))

Special Cases Maximises see below Max 7/12 in (a) If Minimax or Maximin seen send to review



SC Maximises Max M1 A1 A1 A0 M1 A1 A0 M1 A1 A0 B0 B0 (Max 7/12 in (a))

| Stage | State | Action | Dest | Value                          |
|-------|-------|--------|------|--------------------------------|
| March | 3     | 0      | 0    | 210 = 210*                     |
| (3)   | 2     | 1      | 0    | 140 + 60 = 200*                |
|       | 1     | 2      | 0    | 70 + 120 = 190*                |
|       | 0     | 3      | 0    | 180 = 180*                     |
| Feb   | 3     | 1      | 0    | 210 + 60 + 180 = 450           |
| (4)   |       | 2      | 1    | 210 + 120 + 190 = 520          |
|       |       | 3      | 2    | 210 + 180 + 200 = 590          |
|       |       | 4      | 3    | 210 + 240 + 400 + 210 = 1060*  |
|       | 2     | 2      | 0    | 140 + 120 + 180 = 440          |
|       |       | 3      | 1    | 140 + 180 + 190 = 510          |
|       |       | 4      | 2    | 140 + 240 + 400 + 200 = 980    |
|       |       | 5      | 3    | 140 + 300 + 400 + 210 = 1050*  |
|       | 1     | 3      | 0    | 70 + 180 + 180 = 430           |
|       |       | 4      | 1    | 70 + 240 + 400 + 190 = 900     |
|       |       | 5      | 2    | 70 + 300 + 400 + 200 = 970*    |
|       | 0     | 4      | 0    | 240 + 400 + 180 = 820          |
|       |       | 5      | 1    | 300 + 400 + 190 = 890*         |
| Jan   | 3     | 3      | 0    | 210 + 180 + 890 = 1280         |
| (6)   |       | 4      | 1    | 210 + 240 + 400 + 970 = 1820   |
|       |       | 5      | 2    | 210 + 300 + 400 + 1050 = 1960* |
|       | 2     | 4      | 0    | 140 + 240 + 400 + 890 = 1670   |
|       |       | 5      | 1    | 140 + 300 + 400 + 970 = 1810*  |
|       | 1     | 5      | 0    | 70 + 300 + 400 + 890 = 1660*   |
| Dec   | 3     | 3      | 1    | 210 + 180 + 1660 = 2050        |
| (5)   |       | 4      | 2    | 210 + 240 + 400 + 1810 = 2660  |
|       |       | 5      | 3    | 210 + 300 + 400 + 1960 = 2870* |
|       | 2     | 4      | 1    | 140 + 240 + 400 + 1660 = 2440  |
|       |       | 5      | 2    | 140 + 300 + 400 + 1810 = 2650* |
|       | 1     | 5      | 1    | 70 + 300 + 400 + 1660 = 2430*  |
| Nov   | 0     | 3      | 1    | 180 + 2430 = 2610              |
| (2)   |       | 4      | 2    | 240 + 400 + 2650 = 3290        |
|       |       | 5      | 3    | 300 + 400 + 2870 = 3570*       |

