edexcel

# Mark Scheme (Results)

## Summer 2015

## Pearson Edexcel GCE in Decision Mathematics 2 (6690/01)

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

## EDEXCEL GCE MATHEMATICS

## General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

- **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
- **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
- **B** marks are unconditional accuracy marks (independent of M marks)
- Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol $\surd$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- $*$ The answer is printed on the paper
- ⌐ The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
    - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.

- If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

| Question Number | Scheme | Marks |
|---|---|---|
| **1.(a)** | | M1<br>A1<br>M1<br>A1ft<br>A1 **(5)** |
| **(b)** | $P + \frac{7}{2}y + z + \frac{3}{4}s = 15$<br>$r = 5,\ \ s = 0,\ \ t = 3$ | B1ft<br>B1 **(2)**<br>**7 marks** |

| b.v. | $x$ | $y$ | $z$ | $r$ | $s$ | $t$ | Value | Row ops |
|---|---|---|---|---|---|---|---|---|
| $r$ | 0 | $-5$ | 5 | 1 | $-\frac{1}{2}$ | 0 | 5 | $R_1 - 2R_2$ |
| $x$ | 1 | $\frac{1}{2}$ | $-2$ | 0 | $\frac{1}{4}$ | 0 | 5 | $R_2 \div 4$ |
| $t$ | 0 | $-\frac{3}{2}$ | 6 | 0 | $-\frac{1}{4}$ | 1 | 3 | $R_3 - R_2$ |
| $P$ | 0 | $\frac{7}{2}$ | 1 | 0 | $\frac{3}{4}$ | 0 | 15 | $R_4 + 3R_2$ |

**Notes for Question 1**

a1M1: Correct pivot located (4 in column *x*), attempt to divide row
a1A1: Pivot row correct **including change of b.v.**
a2M1: **All** values in one of the non-pivot rows correct **or** one of the non zero and one columns (*y*, *z*, *s* or value) correct following through their choice of pivot from column *x*
a2A1ft: Row operations used correctly at least twice, i.e. **two** of the non zero and one columns (*y*, *z*, *s* or value) correct following through their choice of pivot from column *x*
a3A1: CAO – no follow through – all values and row operations correctly stated – allow if row operations given in terms of old row 2 – **ignore b.v. column for this mark**

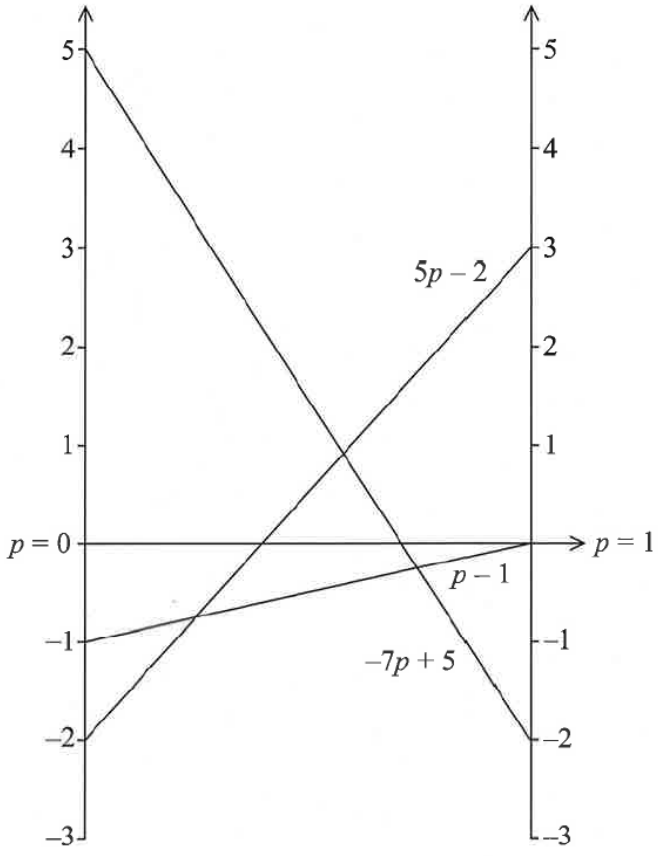
b1B1ft: Follow their profit equation from (a) dependent on scoring **both** M marks in (a)
b2B1: CAO (no follow through) for slack variables ($r = 5$, $s = 0$, $t = 3$)

Pivoting on the 1 in the *x*-column

| b.v. | $x$ | $y$ | $z$ | $r$ | $S$ | $t$ | V |
|---|---|---|---|---|---|---|---|
| $r$ | 0 | -2 | -7 | 1 | 0 | -2 | -1 |
| $s$ | 0 | 6 | -24 | 0 | 1 | -4 | -12 |
| $x$ | 1 | -1 | 4 | 0 | 0 | 1 | 8 |
| $P$ | 0 | -1 | 19 | 0 | 0 | 3 | 24 |

Pivoting on the 2 in the *x*-column

| b.v. | $x$ | $y$ | $z$ | $r$ | $s$ | $t$ | V |
|---|---|---|---|---|---|---|---|
| $x$ | 1 | -2 | 0.5 | 0.5 | 0 | 0 | 7.5 |
| $s$ | 0 | 10 | -10 | -2 | 1 | 0 | -10 |
| $t$ | 0 | 1 | 3.5 | -0.5 | 0 | 1 | 0.5 |
| $P$ | 0 | -4 | 8.5 | 1.5 | 0 | 0 | 22.5 |

| Question Number | Scheme | Marks |
|---|---|---|
| **2.(a)** | The gains (or losses) made by one player are exactly balanced by the losses (or gains) made by the other player. | B1 **(1)** |
| **(b)** | 5 | B1 **(1)** |
| **(c)** | Row minimum {-3,0,-5} Row maximin = 0<br>Column maximum {2,4,2} Column minimax = 2<br>$0 \neq 2$ so no stable solution | M1<br>A1<br>A1 **(3)** |
| **(d)** | Column 1 dominates column 2 so remove column 2<br>$\begin{pmatrix} 3 & 0 & -2 \\ -2 & -1 & 5 \end{pmatrix}$ | B1<br>B1ft B1 **(3)** |
| **(e)** | (Let $p$ = probability that Greg plays new row 1)<br>If R plays 1: G's expected winnings = $3p - 2(1-p)$ $(= 5p - 2)$<br>If R plays 2: G's expected winnings = $0p - 1(1-p)$ $(= p - 1)$<br>If R plays 3: G's expected winnings = $-2p + 5(1-p)$ $(= -7p + 5)$<br>  <br><br>$p - 1 = -7p + 5$<br>$8p = 6$<br>$p = \frac{3}{4}$<br>G should play 1 with probability $\frac{3}{4}$, 2 never and play 3 with probability $\frac{1}{4}$<br>The value of the game to G is $-\frac{1}{4}$ | M1<br>A1<br><br>B2, 1ft, 0<br><br>DM1 A1<br><br>A1ft<br>A1 **(8)**<br>**16 marks** |

| Question Number | Scheme | Marks |
|---|---|---|

**Notes for Question 2**

a1B1: CAO (indication that **either** the losses of one (player) are balanced by the gains of the other (player) **or** that the total points scored by both (players) is zero)

b1B1: CAO (5)

c1M1: Clear attempt to find the Row maximin and Column minimax (either the Row minimums or Column maximums correct **or** at least four (of the six) values stated correctly)
c1A1: Correct Row maximin **and** Column minimax (dependent on all row mins **and** column maxs correct)
c2A1: CAO (so both previous marks must have been awarded) states $0 \neq 2$ (or row (maximin) $\neq$ col (minimax) as long as 0 is clearly identified as the row maximin and 2 as the column minimax) **and** draws the correct conclusion

d1B1: CAO (accept reduced matrix or 'column 1 dominates column 2' or column crossed out). Allow recovery later (**seeing the correct 2 × 3 matrix implies all three marks in this part**)
d2B1ft: Either 3 × 2 matrix with correct values **for G** (so all signs changed correctly) or 2 × 3 matrix with correct values **for G** (condone incorrect signs). If incorrect column deleted (so B0 for first mark in this part) then allow this mark on the ft for their 3 × 2 matrix transposed 'correctly' **for G** (both values **and** signs 'correct')
d3B1: CAO

e1M1: Setting up all three probability expressions (allow $p - 1$), implicit definition of '$p$'
e1A1: CAO (condone incorrect simplification)
e1B1ft: Attempt at three lines (correct slant direction and relative intersection with 'axes'), accept $p > 1$ or $p < 0$ here but must go from 'axis' to 'axis' (give bod if close). Must be functions of $p$
e2B1: CAO $0 \leq p \leq 1$, scaling correct and clear (expect to see 1 line = 1, although other scalings are acceptable eg 1 line = 2), condone lack of labels. Rulers used
e2DM1: Finding their correct optimal point, must have three lines and set up an equation to find $0 \leq p \leq 1$. Dependent on first B mark in this part. Must have three intersection points. Solving all three simultaneous equations and stating incorrect $p$ is M0
e2A1: CSO (must have scored all previous marks in (e))
e3A1ft: All three options listed must ft from their $p$ ($0 \leq p \leq 1$), check page 1 for G should never play 2. Dependent on both previous M marks in this part
e4A1: CAO $\left(-\frac{1}{4}\right)$

**SC1**: If column 1 is deleted in (d) candidates can earn a maximum in (e) of

M1 A0 B1 B0 M1 A0 A1 A1 (max. of 5) – the penultimate A mark is for G should play 1 never, play 2 and 3 with probability $\frac{1}{2}$, final A mark is for the value of the game being $-\frac{3}{2}$

**SC2**: If column 3 is deleted in (d) candidates can earn a maximum in (e) of

M1 A0 B1 B0 M0 A0 A0 A0 (max. of 2)

| Question Number | Scheme | Marks |
|---|---|---|
| **3.(a)** | Prim: AF, EF, BE, BC, CD, DG | M1 A1 **(2)** |
| **(b)** | $2 \times 136 = 272$ (km) | B1 **(1)** |
| **(c)** | A F E B C D G A<br>21 20 19 27 24 25 30 = 166 (km) | B1<br>B1 **(2)** |
| **(d)** | Starting at F route length is $153 + x$<br>With $x > 21$, $153 + x$ is greater than 166 so the better upper bound is the one starting at A | B1<br>DB1 **(2)** |
| **(e)** | Length of RMST = 115<br>$115 + 21 + x = 159 \therefore x = 23$ (km) | B1<br>M1 A1 **(3)** |
| **(f)** | $159 \leq$ optimal $\leq 166$ [accept $159 <$ optimal $\leq 166$] | B2,1,0 **(2)**<br>**12 marks** |

**Notes for Question 3**

a1M1: Must be using Prim's algorithm not NNA – if any arc creates a cycle then M0. First four arcs (or all 7 nodes / or numbers across the top of the matrix) selected correctly. Award M1 only for a correct tree with no working. Award M1 only for the first four arcs (oe) selected correctly if starting at a different node than A
a1A1: CAO (order of arc selection clear)

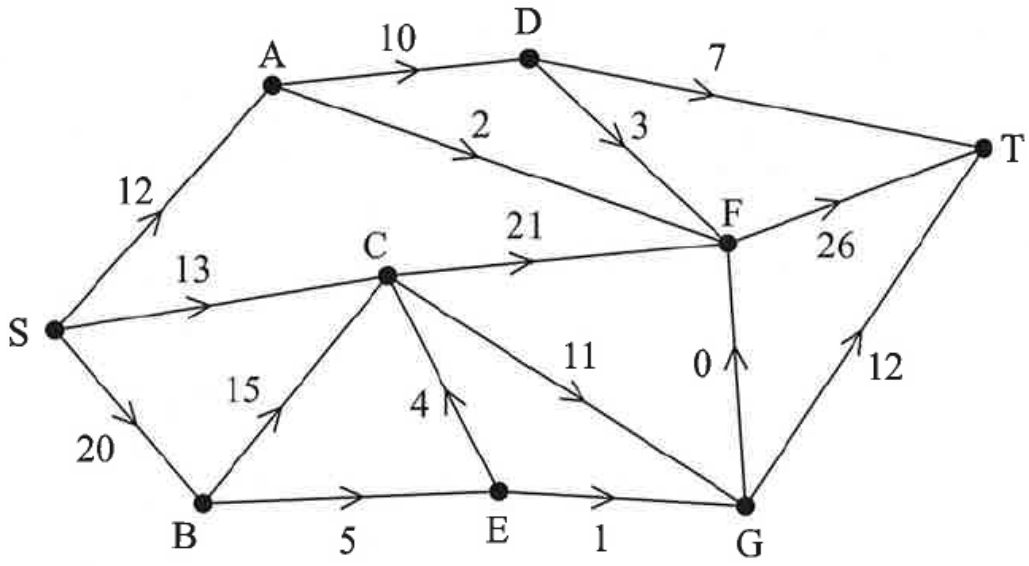
b1B1: CAO (272)

c1B1: CAO – must be either in terms of nodes or arcs (not weights)
c2B1: CAO (166)

d1B1: Either $153 + x$ **or** states a value in the interval $174 <$ value $< 180$ **or** considers one of the intervals $174 <$ value $< 180$ **or** $175 \leq$ value $\leq 179$
d2DB1: Correct argument that A gives the better upper bound. Must be considering either $x > 21$ or $x \geq 22$ with 153 (so expect to see as a minimum the mention of $> 174$ or $\geq 175$) – must be clear that the upper bound starting at A is the better upper bound. This mark is dependent on the previous B mark in (d)

e1B1: CAO (length of RMST) – the length (115 or 19 + 20 + 27 + 24 + 25) must be either explicitly stated **or** seen in their working (not just implied by their working)
e1M1: Adding the **correct** two least values (21 and $x$) to **their** RMST length (their RMST may be incorrect but must contain only 5 arcs) and equating to 159. Accept, for example, $136 + x = 159$ or $136 + 23 = 159$ or $115 + 21 + 23 = 159$ or equivalent calculations using the length of their RMST
e1A1: CAO (must be clear that ($x =$) 23 not just embedded in a calculation)

f1B1: Any indication of an interval containing 159 (as a lower bound) and **their** stated better upper bound from (d)
f2B1: CAO either $159 \leq$ optimal (oe) $\leq 166$ or $159 <$ optimal (oe) $\leq 166$

| Question Number | Scheme | Marks |
|---|---|---|
| **4.(a)** | $C_1 = 45,\ C_2 = 73$ | B1 B1 **(2)** |
| **(b)** | 45 | B1ft **(1)** |
| **(c)** | 20 | B1 **(1)** |
| **(d)** | The maximum capacity of the arcs flowing into G is 21 and so both GF and GT cannot be full to capacity as the capacity of the arcs flowing out of G is 26 | B1 **(1)** |
| **(e)** |  | M1 A1 **(2)**<br>**7 marks** |

**Notes for Question 4**

a1B1: CAO for $C_1$(45)
a2B1: CAO for $C_2$ (73)

b1B1ft: 45 or the value of their smallest cut from (a)

c1B1: CAO (20)

d1B1: CAO – argument must be numerical in nature (as a minimum accept 26 > 21 (oe))

e1M1: Consistent flow pattern – check each node, must have exactly 1 number per arc (arc EC must be 4, AD – 10 and DF – 3 but all other arcs may have over-capacatiated values)
e1A1: CAO

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>5.(a)</td><td>
<table>
<tr><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>A</td><td>$74-\theta$</td><td>$\theta$</td><td></td></tr>
<tr><td>B</td><td></td><td></td><td></td></tr>
<tr><td>C</td><td>$13+\theta$</td><td>$50-\theta$</td><td></td></tr>
<tr><td>D</td><td></td><td></td><td></td></tr>
</table>
giving
<table>
<tr><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>A</td><td>24</td><td>50</td><td></td></tr>
<tr><td>B</td><td>58</td><td></td><td></td></tr>
<tr><td>C</td><td>63</td><td></td><td></td></tr>
<tr><td>D</td><td></td><td>7</td><td>78</td></tr>
</table>
</td><td>M1 A1 (2)</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><td>Shadow costs</td><td></td><td>20</td><td>5</td><td>$-1$</td></tr>
<tr><td></td><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>0</td><td>A</td><td>X</td><td>X</td><td>14</td></tr>
<tr><td>$-13$</td><td>B</td><td>X</td><td>23</td><td>22</td></tr>
<tr><td>$-11$</td><td>C</td><td>X</td><td>20</td><td>33</td></tr>
<tr><td>11</td><td>D</td><td>$-9$</td><td>X</td><td>X</td></tr>
</table>
<table>
<tr><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>A</td><td>$24-\theta$</td><td>$50+\theta$</td><td></td></tr>
<tr><td>B</td><td></td><td></td><td></td></tr>
<tr><td>C</td><td></td><td></td><td></td></tr>
<tr><td>D</td><td>$\theta$</td><td>$7-\theta$</td><td></td></tr>
</table>
giving
<table>
<tr><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>A</td><td>17</td><td>57</td><td></td></tr>
<tr><td>B</td><td>58</td><td></td><td></td></tr>
<tr><td>C</td><td>63</td><td></td><td></td></tr>
<tr><td>D</td><td>7</td><td></td><td>78</td></tr>
</table>
Entering cell DP, exiting cell DQ
</td><td>M1 A1<br><br>M1 A1 (4)</td></tr>
<tr><td>(c)</td><td>
<table>
<tr><td>Shadow costs</td><td></td><td>20</td><td>5</td><td>8</td></tr>
<tr><td></td><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>0</td><td>A</td><td>X</td><td>X</td><td>5</td></tr>
<tr><td>$-13$</td><td>B</td><td>X</td><td>23</td><td>13</td></tr>
<tr><td>$-11$</td><td>C</td><td>X</td><td>20</td><td>24</td></tr>
<tr><td>2</td><td>D</td><td>X</td><td>9</td><td>X</td></tr>
</table>
Optimal since no negative improvement indices
</td><td>M1 A1 A1 (3)</td></tr>
<tr><td>(d)</td><td>(£) 2532</td><td>B1 (1)</td></tr>
<tr><td>(e)</td><td>Let $x_{ij}$ be the number of units transported from $i$ to $j$<br>where $i \in \{A, B, C, D\}$, $j \in \{P, Q, R\}$ and $x_{ij} \geq 0$<br>Minimise (C =) $20x_{AP} + 5x_{AQ} + 13x_{AR} + 7x_{BP} + 15x_{BQ} + 8x_{BR} + 9x_{CP} + 14x_{CQ} + 21x_{CR} + 22x_{DP} + 16x_{DQ} + 10x_{DR}$<br>Subject to $x_{AP} + x_{AQ} + x_{AR} \leq 74$ or $\sum x_{Aj} \leq 74$<br>$x_{BP} + x_{BQ} + x_{BR} \leq 58$ or $\sum x_{Bj} \leq 58$<br>$x_{CP} + x_{CQ} + x_{CR} \leq 63$ or $\sum x_{Cj} \leq 63$<br>$x_{DP} + x_{DQ} + x_{DR} \leq 85$ or $\sum x_{Dj} \leq 85$<br>$x_{AP} + x_{BP} + x_{CP} + x_{DP} \leq 145$ $\sum x_{iP} \leq 145$<br>$x_{AQ} + x_{BQ} + x_{CQ} + x_{DQ} \leq 57$or $\sum x_{iQ} \leq 57$<br>$x_{AR} + x_{BR} + x_{CR} + x_{DR} \leq 78$ or $\sum x_{iR} \leq 78$</td><td>B1<br>B1<br>M1 A1<br><br><br><br><br>M1<br>A1<br>A1 (7)<br>17 marks</td></tr>
</table>

| Question Number | Scheme | Marks |
|---|---|---|

**Notes for Question 5**

a1M1: A valid route, only one empty square, AQ used, $\theta$'s balance
a1A1: Correct route, up to an improved solution (six numbers no zeros)

b1M1: Finding 7 shadow costs and 6 Improvement indices
b1A1: Shadow costs [Alt: A(20), B(7), C(9), D(31), P (0), Q(−15), R(−21)] and improvement indices CAO
b2M1: A valid route, their most negative II chosen, only one empty square used, $\theta$'s balance
b2A1: CSO (for part (b)) (entering DP, and exiting DQ clearly stated)

c1M1: Finding 7 shadow costs **and** all 6 IIs **or** at least 1 negative II found
c1A1: CAO for the shadow costs [Alt: A(20), B(7), C(9), D(22), P(0), Q(−15), R(−12)] and 6 positive II
c2A1: CSO (for part (c)) + reason + optimal

d1B1: CAO (2532)

e1B1: $x_{ij}$ (not just *x*) defined correctly (must include 'number of' (oe) and 'from *i* to *j*' (oe)). Withold this mark if $x_{ij}$is further defined as taking the values of either 0 or 1
e2B1: Defining the set of values for *i* and *j* **including** non-negativity constraint - withold this mark if definition is inconsistent with their later use in the objective function and constraints (eg A, B,… in the definition but 1, 2,… used in constraints and objective)
e1M1: Objective function (allow one error either in coefficient **or** variable) – minimise **not** required for this mark
e1A1: CAO – Correct objective function and minimise
e2M1: At least 3 constraints listed with unit coefficients (accept = or any inequality for the M mark) – rhs values must be correct
e2A1: At least 5 correct constraints (accept consistent use of = or $\leq$ on at least 5)
e3A1: All 7 constraint correct (accept consistent use of = or $\leq$ on all 7)

Note: if there are inconsistencies between the constraints and the objective function then mark to the benefit of the candidate. For example, a candidate who correctly defines $x_{ij}$and its set of values and writes down the constraints correctly (based on their definition of $x_{ij}$) but in the objective function omits the *x* (so uses, for example, AP, AQ, etc.) then this would scored B1B1M0A0M1A1A1

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>6.(a)</td><td>Maximin</td><td>B1 (1)</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><th>Stage</th><th>State</th><th>Action</th><th>Destination</th><th>Value</th></tr>
<tr><td>3</td><td>G</td><td>GT</td><td>T</td><td>8*</td></tr>
<tr><td></td><td>H</td><td>HT</td><td>T</td><td>5*</td></tr>
<tr><td></td><td>J</td><td>JT</td><td>T</td><td>6*</td></tr>
<tr><td>2</td><td>D</td><td>DH</td><td>H</td><td>min (10, 5) = 5*</td></tr>
<tr><td></td><td>E</td><td>EG<br>EH<br>EJ</td><td>G<br>H<br>J</td><td>min (9, 8) = 8*<br>min (8, 5) = 5<br>min (7, 6) = 6</td></tr>
<tr><td></td><td>F</td><td>FH<br>FJ</td><td>H<br>J</td><td>min (8, 5) = 5*<br>min (5, 6) = 5*</td></tr>
<tr><td>1</td><td>A</td><td>AD<br>AE</td><td>D<br>E</td><td>min (8, 5) = 5<br>min (6, 8) = 6*</td></tr>
<tr><td></td><td>B</td><td>BE<br>BF</td><td>E<br>F</td><td>min (17, 8) = 8*<br>min (9, 5) = 5</td></tr>
<tr><td></td><td>C</td><td>CD<br>CF</td><td>D<br>F</td><td>min (10, 5) = 5*<br>min (10, 5) = 5*</td></tr>
<tr><td>0</td><td>S</td><td>SA<br>SB<br>SC</td><td>A<br>B<br>C</td><td>min (11, 6) = 6<br>min (8, 8) = 8*<br>min (12, 5) = 5</td></tr>
</table>
</td><td>M1 A1<br><br>M1 A1 A1<br><br>M1 A1ft A1<br><br>M1 A1 (10)</td></tr>
<tr><td>(c)</td><td>Maximum weight = 8 (tonnes)</td><td>B1 (1)</td></tr>
<tr><td>(d)</td><td>Route: S – B – E – G – T</td><td>B1 (1)</td></tr>
<tr><td>(e)(i)<br>(ii)</td><td>Increase HT (by 5) to 10<br>Maximum weight = 10 (tonnes)<br>New route: S – C – D – H – T</td><td>B1<br>B1<br>B1 (3)<br>16 marks</td></tr>
</table>

| Question Number | Scheme | Marks |
|---|---|---|

**Notes for Question 6**

a1B1: 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**

**2nd, 3rd and 4th M marks - must bring earlier optimal results into calculations at least once**

**Penalise lack of * only once**

b1M1: First stage completed. 3 rows, something in each cell
b1A1: CAO condone missing * here
b2M1: Second stage completed with 3 states and at least 6 rows. Bod if something in each cell
b2A1: Second stage any 2 states correct
b3A1: CAO all 3 states correct (no missing/extra rows)
b3M1: Third stage completed with 3 states and at least 6 rows. Bod if something in each cell
b4A1ft: Third stage any two states correct. Follow through their * values or the correct * values
b5A1: CAO all 3 states correct (no missing/extra rows)
b4M1: Fourth stage completed with 1 state and at least 3 rows. Bod if something in each cell
b6A1: CAO final state correct (no missing/extra rows)

c1B1: CAO weight (8) (dependent on scoring **all** M marks in (b))

d1B1: CAO route (S – B – E – G – T) (dependent on scoring **all** M marks in (b))

e1B1: Indication of either increasing HT by 5 or increasing HT to 10
e2B1: CAO (10)
e3B1: CAO (S – C – D – H – T)

**Special Cases for (b), (c) and (d)**

**SC1 Minimax**: M1 A1 M1 A0 A0 M1 A1 A0 M1 A0 B1 B1 (Max 8/12)
**SC2 Maximum**: M1 A1 M1 A0 A0 M1 A0 A0 M1 A0 B0 B1 (Max 6/12)
**SC3 Minimum**: As above (SC2)
**SC4 Maximax**: M1 A1 M1 A0 A0 M1 A0 A0 M1 A0 B0 B0 (Max 5/12)
**SC5 Minimin**: As above (SC4)
**SC6 Working forwards**: M1 A0 M1 A0 A0 M1 A0 A0 M1 A0 B0 B0 (Max 4/12)
**SC7 Reversed states**: M1 A0 M1 A0 A0 M1 A0 A0 M1 A1 B1 B1 (Max 7/12)

| Question Number | Scheme | Marks |
|---|---|---|

**SC1 Minimax**:

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | G | GT | T | 8* |
| | H | HT | T | 5* |
| | J | JT | T | 6* |
| 2 | D | DH | H | max (10, 5) = 10* |
| | E | EG | G | max (9, 8) = 9 |
| | | EH | H | max (8, 5) = 8 |
| | | EJ | J | max (7, 6) = 7* |
| | F | FH | H | max (8, 5) = 8 |
| | | FJ | J | max (5, 6) = 6* |
| 1 | A | AD | D | max (8, 10) = 10 |
| | | AE | E | max (6, 7) = 7* |
| | B | BE | E | max (17, 7) = 17 |
| | | BF | F | max (9, 6) = 9* |
| | C | CD | D | max (10, 10)=10* |
| | | CF | F | max (10, 6) = 10* |
| 0 | S | SA | A | max (11, 7) = 11 |
| | | SB | B | max (8, 9) = 9* |
| | | SC | C | max (12, 10) = 12 |

Weight: 9 Route: S – B – F – J – T

**SC2 Maximum:**

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | G | GT | T | 8* |
| | H | HT | T | 5* |
| | J | JT | T | 6* |
| 2 | D | DH | H | 10 + 5 = 15* |
| | E | EG | G | 9 + 8 = 17* |
| | | EH | H | 8 + 5 = 13 |
| | | EJ | J | 7 + 6 = 13 |
| | F | FH | H | 8 + 5 = 13* |
| | | FJ | J | 5 + 6 = 11 |
| 1 | A | AD | D | 8 + 15 = 23* |
| | | AE | E | 6 + 17 = 23* |
| | B | BE | E | 17 + 17 = 34* |
| | | BF | F | 9 + 13 = 22 |
| | C | CD | D | 10 + 15 = 25* |
| | | CF | F | 10 + 13 = 23 |
| 0 | S | SA | A | 11 + 23 = 34 |
| | | SB | B | 8 + 34 = 42* |
| | | SC | C | 12 + 25 = 37 |

Route: S – B – E – G – T

| Question Number | Scheme | Marks |
|---|---|---|

**SC3 Minimum:**

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | G | GT | T | 8* |
| | H | HT | T | 5* |
| | J | JT | T | 6* |
| 2 | D | DH | H | 10 + 5 = 15* |
| | E | EG | G | 9 + 8 = 17 |
| | | EH | H | 8 + 5 = 13* |
| | | EJ | J | 7 + 6 = 13* |
| | F | FH | H | 8 + 5 = 13 |
| | | FJ | J | 5 + 6 = 11* |
| 1 | A | AD | D | 8 + 15 = 23 |
| | | AE | E | 6 + 13 = 19* |
| | B | BE | E | 17 + 13 = 30 |
| | | BF | F | 9 + 11 = 20* |
| | C | CD | D | 10 + 15 = 25 |
| | | CF | F | 10 + 11 = 21* |
| 0 | S | SA | A | 11 + 19 = 30 |
| | | SB | B | 8 + 20 = 28* |
| | | SC | C | 12 + 21 = 33 |

Route: S – B – F – J – T

**SC4 Maximax**:

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | G | GT | T | 8* |
| | H | HT | T | 5* |
| | J | JT | T | 6* |
| 2 | D | DH | H | max (10, 5) = 10* |
| | E | EG | G | max (9, 8) = 9* |
| | | EH | H | max (8, 5) = 8 |
| | | EJ | J | max (7, 6) = 7 |
| | F | FH | H | max (8, 5) = 8* |
| | | FJ | J | max (5, 6) = 6 |
| 1 | A | AD | D | max (8, 10) = 10* |
| | | AE | E | max (6, 9) = 9 |
| | B | BE | E | max (17, 9) = 17* |
| | | BF | F | max (9, 8) = 9 |
| | C | CD | D | max (10, 10)=10* |
| | | CF | F | max (10, 8) = 10* |
| 0 | S | SA | A | max (11, 10) = 11 |
| | | SB | B | max (8, 17) = 17* |
| | | SC | C | max(12, 10) =12 |

| Question Number | Scheme | Marks |
|---|---|---|

**SC5 Minimin**:

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | G | GT | T | 8* |
| | H | HT | T | 5* |
| | J | JT | T | 6* |
| 2 | D | DH | H | min (10, 5) = 5* |
| | E | EG | G | min (9, 8) = 8 |
| | | EH | H | min (8, 5) = 5* |
| | | EJ | J | min (7, 6) = 6 |
| | F | FH | H | min (8, 5) = 5* |
| | | FJ | J | min (5, 6) = 5* |
| 1 | A | AD | D | min (8, 5) = 5* |
| | | AE | E | min (6, 5) = 5* |
| | B | BE | E | min (17, 5) = 5* |
| | | BF | F | min (9, 5) = 5* |
| | C | CD | D | min (10, 5) = 5* |
| | | CF | F | min (10, 5) = 5* |
| 0 | S | SA | A | min (11, 5) = 5* |
| | | SB | B | min (8, 5) = 5* |
| | | SC | C | min (12, 5) = 5* |

**SC6 Working forwards S to T:**

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | A | AS | S | 11* |
| | B | BS | S | 8* |
| | C | CS | S | 12* |
| 2 | D | DA | A | min (8, 11) = 8 |
| | | DC | C | min (10, 12) =10* |
| | E | EA | A | min (6, 11) = 6 |
| | | EB | B | min (17, 8) = 8* |
| | F | FB | B | min (9, 8) = 8 |
| | | FC | C | min (10, 12) =10* |
| 1 | G | GE | E | min (9, 8) = 8* |
| | H | HD | D | min (10, 12) =10* |
| | | HE | E | min (8, 8) = 8 |
| | | HF | F | min (8, 10) = 8 |
| | J | JE | E | min (7, 8) = 7* |
| | | JF | F | min (5, 10) = 5 |
| 0 | T | TG | G | min (8, 8) = 8* |
| | | TH | H | min (5, 10) = 5 |
| | | TJ | J | min (6, 7) = 6 |

| Question Number | Scheme | Marks |
|---|---|---|

**SC7 Reversed States:**

| Stage | State | Action | Destination | Value |
|---|---|---|---|---|
| 3 | T | TG | G | 8* |
| | | TH | H | 5* |
| | | TJ | J | 6* |
| 2 | G | GE | E | min (9, 8) = 8* |
| | H | HD | D | min (10, 5) = 5* |
| | | HE | E | min (8, 5) = 5 |
| | | HF | F | min (8, 5) = 5* |
| | J | JE | E | min(7, 6) = 6 |
| | | JF | F | min (5, 6) = 5* |
| 1 | D | DA | A | min (8, 5) = 5 |
| | | DC | C | min (10, 5) = 5* |
| | E | EA | A | min (6, 8) = 6* |
| | | EB | B | min (17, 8) = 8* |
| | F | FB | B | min (9, 5) = 5 |
| | | FC | C | min (10, 5) = 5* |
| 0 | A | AS | S | min (11, 6) = 6 |
| | B | BS | S | min (8, 8) = 8* |
| | C | CS | S | min (12, 5) = 5 |

Weight: 8  Route: S – B – E – G – T

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