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Mark Scheme (Results)

June 2011

GCE Decision D2 (6690) Paper 1

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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.

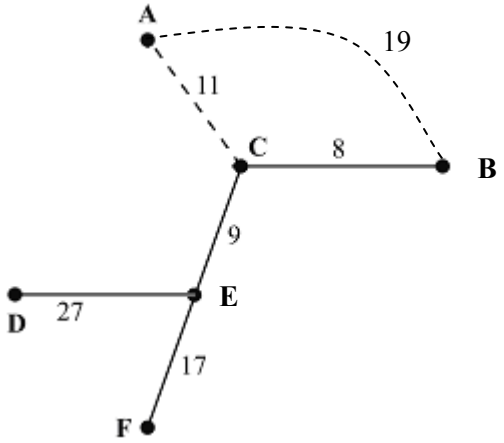
3. Abbreviations

   These are some of the traditional marking abbreviations that will appear in the mark schemes and can be used if you are using the annotation facility on ePEN.

   - bod – benefit of doubt
   - ft – follow through
   - the symbol $\hat{}$ 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

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June 2011
Decision Mathematics D2 6690
Mark Scheme

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>1.
(a)</td><td>
<table>
<tr><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>A</td><td>-</td><td>19</td><td>11</td><td>23</td><td>20</td><td>37</td></tr>
<tr><td>B</td><td>19</td><td>-</td><td>8</td><td>42</td><td>17</td><td>32</td></tr>
<tr><td>C</td><td>11</td><td>8</td><td>-</td><td>34</td><td>9</td><td>26</td></tr>
<tr><td>D</td><td>23</td><td>42</td><td>34</td><td>-</td><td>27</td><td>31</td></tr>
<tr><td>E</td><td>20</td><td>17</td><td>9</td><td>27</td><td>-</td><td>17</td></tr>
<tr><td>F</td><td>37</td><td>32</td><td>26</td><td>31</td><td>17</td><td>-</td></tr>
</table>
</td><td>B3, 2, 1, 0
(3)</td></tr>
<tr><td>(b)</td><td>A C B E F D A
11 8 17 17 31 23 = 107</td><td>M1 A1
A1
(3)</td></tr>
<tr><td>(c)</td><td>Delete A


RMST weight = 61
Lower bound = 61 + 11 + 19 = 91 km</td><td>M1

A1
M1 A1
(4)
10</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>(a)1B1
2B1
3B1
(b)M1
1A1
2A1
(c)1M1
1A1
2M1
2A1</td><td><u>Notes:</u>
One double entry correct
Two double entries correct
Three double entries correct
NN route, each letter appearing once, condone lack of return vertex
CAO
CAO
Finding my RMST – accept 61 for both marks
Either 8 + 9 + 17 + 27 or 61 seen
Adding on two least arcs, accept 11 and 19 or AC and AB
91 CAO</td><td></td></tr>
<tr><td>2.
(a)</td><td>Adds a column of four zeros and 10.

<table>
<tr><td>Shadow costs</td><td></td><td>31</td><td>42</td><td>47</td><td>9</td></tr>
<tr><td></td><td></td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>0</td><td>1</td><td>x</td><td>-13</td><td>-15</td><td>-9</td></tr>
<tr><td>-9</td><td>2</td><td>x</td><td>x</td><td>-11</td><td>0</td></tr>
<tr><td>-15</td><td>3</td><td>9</td><td>x</td><td>x</td><td>6</td></tr>
<tr><td>-9</td><td>4</td><td>1</td><td>-7</td><td>x</td><td>x</td></tr>
</table></td><td>B1
(1)

M1
A1
M1
A1
(4)</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><td></td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>1</td><td>20 – θ</td><td></td><td>θ</td><td></td></tr>
<tr><td>2</td><td>15 + θ</td><td>7 – θ</td><td></td><td></td></tr>
<tr><td>3</td><td></td><td>18 + θ</td><td>2 – θ</td><td></td></tr>
<tr><td>4</td><td></td><td></td><td>28</td><td>10</td></tr>
</table>
Entering cell: 1C Exiting cell: 3C</td><td>M1

A1ft</td></tr>
<tr><td>(c)</td><td>
<table>
<tr><td></td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>1</td><td>18</td><td></td><td>2</td><td></td></tr>
<tr><td>2</td><td>17</td><td>5</td><td></td><td></td></tr>
<tr><td>3</td><td></td><td>20</td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td>28</td><td>10</td></tr>
</table></td><td>DM1 A1
(4)
9</td></tr>
</table>

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>(a)

(b)

(c)</td><td><u>Notes:</u>
1B1: cao

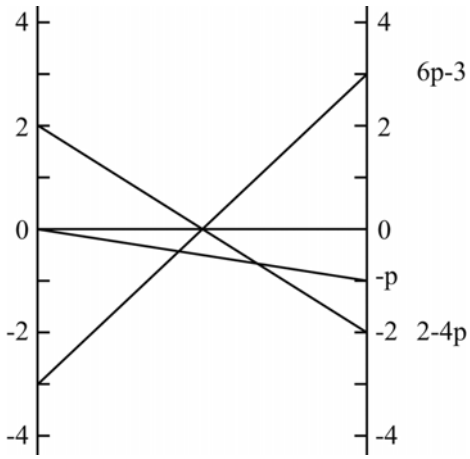
1M1: Finding all 8 shadow costs
1A1: cao
2M1: Finding missing four improvement indices – no extra zeros
2A1: cao

1M1: A valid route, their most negative II chosen, only one empty square used, θ's balance.
1A1ft: consistent; their entering and exiting cells stated clearly
2DM1: An improved solution 7 entries only, (so must now be using one of my negative indices as the entering cell). Must ft from their valid route.
2A1: cao</td><td></td></tr>
<tr><td>3.
(a)</td><td>$P - 7x + z + 4s = 320$</td><td>M1 A1
(2)</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><td>b.v</td><td>x</td><td>y</td><td>z</td><td>r</td><td>s</td><td>t</td><td>Value</td></tr>
<tr><td>r</td><td>$-\frac{1}{2}$</td><td>0</td><td>2</td><td>1</td><td>$-\frac{1}{2}$</td><td>0</td><td>10</td></tr>
<tr><td>y</td><td>$\frac{1}{2}$</td><td>1</td><td>$\frac{3}{4}$</td><td>0</td><td>$\frac{1}{4}$</td><td>0</td><td>5</td></tr>
<tr><td>t</td><td>$\frac{1}{2}$</td><td>0</td><td>1</td><td>0</td><td>$-\frac{1}{4}$</td><td>1</td><td>4</td></tr>
<tr><td>P</td><td>-7</td><td>0</td><td>1</td><td>0</td><td>4</td><td>0</td><td>320</td></tr>
</table>
<table>
<tr><td>b.v.</td><td>x</td><td>y</td><td>z</td><td>r</td><td>s</td><td>t</td><td>Value</td><td>Row ops.</td></tr>
<tr><td>r</td><td>0</td><td>0</td><td>3</td><td>1</td><td>$-\frac{3}{4}$</td><td>1</td><td>14</td><td>$R_1 + \frac{1}{2}R_3$</td></tr>
<tr><td>y</td><td>0</td><td>1</td><td>$-\frac{1}{4}$</td><td>0</td><td>$\frac{1}{2}$</td><td>- 1</td><td>1</td><td>$R_2 - \frac{1}{2}R_3$</td></tr>
<tr><td>x</td><td>1</td><td>0</td><td>2</td><td>0</td><td>$-\frac{1}{2}$</td><td>2</td><td>8</td><td>$R_3 \div \frac{1}{2}$</td></tr>
<tr><td>P</td><td>0</td><td>0</td><td>15</td><td>0</td><td>$\frac{1}{2}$</td><td>14</td><td>376</td><td>$R_4 + 7R_3$</td></tr>
</table>
</td><td>2M1 2A1ft

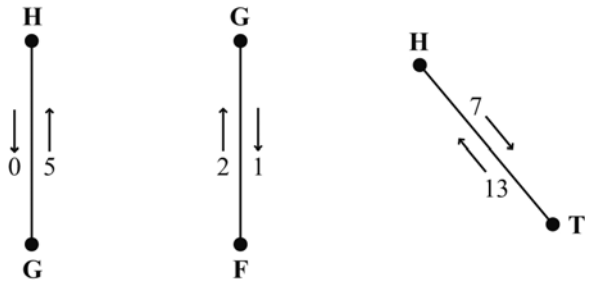
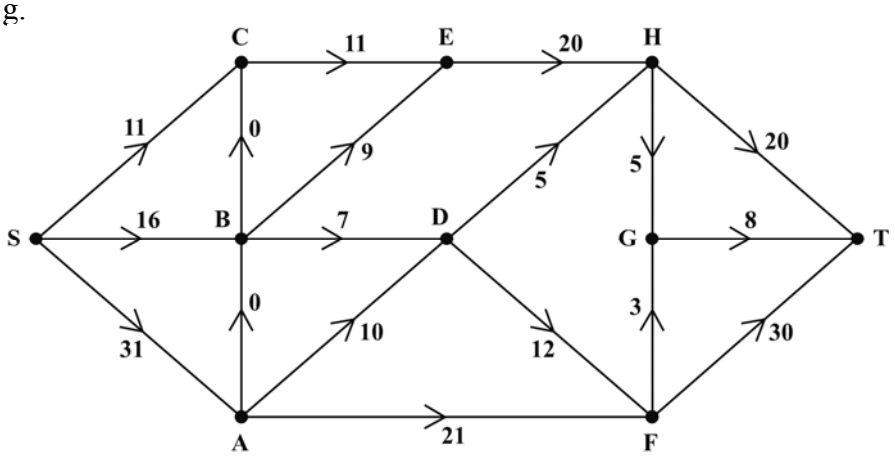
1M1 2A1

3A1
(5)</td></tr>
<tr><td>(c)</td><td>$P = 376 \quad x = 8 \quad y = 1 \quad z = 0 \quad r = 14 \quad s = 0 \quad t = 0$</td><td>M1 A1ft A1
(3)
10</td></tr>
</table>

Question Number	Scheme	Marks
	Notes:	
(a)	1M1: One equal sign, P and 320 present 1A1: cao	
(b)	1M1: correct pivot located, attempt to divide row. If choosing negative pivot M0M0 in (b) 1A1: pivot row correct including change of b.v. 2M1: (ft) Correct row operations used at least once or stated correctly. 2A1ft: Looking at non zero-and-one columns, one column ft correct 3A1: cao.	
(c)	1M1: At least 4 values stated. Reading off bottom row, or negative values get M0. 1A1ft: Their four basic variables correct ft from their table. 2A1: cao	

Question Number	Scheme	Marks
4. **(a)**	<table><tr><td></td><td>S plays 1</td><td>S plays 2</td><td>S plays 3</td></tr><tr><td>L plays 1</td><td>-4</td><td>-1</td><td>1</td></tr><tr><td>L plays 2</td><td>3</td><td>-1</td><td>-2</td></tr><tr><td>L plays 3</td><td>-3</td><td>0</td><td>2</td></tr></table> Row 3 dominates row 1 so row 1 may be deleted. <table><tr><td></td><td>S plays 1</td><td>S plays 2</td><td>S plays 3</td></tr><tr><td>L plays 2</td><td>3</td><td>-1</td><td>-2</td></tr><tr><td>L plays 3</td><td>-3</td><td>0</td><td>2</td></tr></table> Let Laura play 2 with probability p and 3 with probability (1- p) If Sam plays 1: Laura's gain is $3p - 3(1- p) = -3 + 6p$ If Sam plays 2: Laura's gain is $-p + 0\,(1- p) = -p$ If Sam plays 3: Laura's gain is $-2p + 2\,(1- p) = 2 - 4p$	M1 M1 A1 (3)
(b)		B2,1ft,0 (2)
(c)	$-3+6p=-p$ $7p=3$ $p=\frac{3}{7}$ Laura should play row 1: never, row 2: $\frac{3}{7}$ of the time and row 3: $\frac{4}{7}$ of the time and the value of the game is $-\frac{3}{7}$ to her.	M1 A1 A1ft A1 (4) **9**

Question Number	Scheme	Marks
	Notes:	
(a)	1M1: Matrix reduced correctly. Could be implicit from equations. 2M1: Setting up three probability equations, implicit definition of p. 1A1: CAO	
(b)	1B1ft: At least two lines correct, accept $p>1$ or $p<0$ here. Must both be function of p. 2B1: 3 lines cao, $0 \leq p \leq 1$, scale clear (or 1 line = 1), condone lack of labels. Rulers used.	
(c)	3M1: Finding their correct optimal point, must have three lines, and setting up an equation to find $0 \leq p \leq 1$. 1A1: CAO 2A1ft: All three options listed must ft from their p, check page 1, no negatives. 3A1: CAO	

Question Number	Scheme	Marks
5. **(a)**	$a = 1$ $b = 5$ $c = 13$ Flow = 49	B1, B1 B1, B1 (4)
(b)		M1 A1 (2)
(c)	e.g. SBEHT - 7 together with either SBEHDAFGT – 2 or SBCEHDAFGT - 2	M1 A1 A2,1,0 (4)
(d)	58	B1 (1)
(e)	e.g. 	M1 A1 (2)
(f)	Max flow = min cut Cut through HT, HG, GF, FT Value 58	M1 A1 (2) **15**

Question Number	Scheme	Marks
	Notes:	
(a)	1B1: a = 1 cao 2B1: b = 5 cao 3B1: c = 13 cao 4B1: 49 cao	
(b)	1M1: Two numbers on each arc 1A1: cao	
(c)	1M1: One valid flow augmenting route found and value stated. 1A1: Flow increased by at least 2 2A1: A second correct flow 3A1: Flow increased by 9 and no more	
(d)	1B1: cao	
(e)	1M1: Consistent flow pattern > 51 1A1: cao	
(f)	1M1: Must have attempted (e), S to T, and made an attempt at a cut. 1A1: cut correct – may be drawn. Refer to max flow-min cut theorem three words out of four.	

Question Number	Scheme	Marks
6. **(a)**	<table><tr><th></th><th>Task A</th><th>Task B</th><th>Task C</th></tr><tr><td>Worker P</td><td>27</td><td>31</td><td>25</td></tr><tr><td>Worker Q</td><td>26</td><td>30</td><td>34</td></tr><tr><td>Worker R</td><td>35</td><td>29</td><td>32</td></tr></table> Let $x_{ij} = \begin{cases} 1 \text{ if worker does the task} \\ 0 \text{ otherwise} \end{cases}$ Where x_{ij} indicates worker i being assigned to task j, $i \in \{P, Q, R\}$, $j \in \{A, B, C\}$ Minimise $27x_{PA} + 31x_{PB} + 25x_{PC} + 26x_{QA} + 30x_{QB} + 34x_{QC} + 35x_{RA} + 29x_{RB} + 32x_{RC}$ Subject to: $x_{PA} + x_{PB} + x_{PC} = 1$ $x_{QA} + x_{QB} + x_{QC} = 1$ $x_{RA} + x_{RB} + x_{RC} = 1$ $x_{PA} + x_{QA} + x_{RA} = 1$ $x_{PB} + x_{QB} + x_{RB} = 1$ $x_{PC} + x_{QC} + x_{RC} = 1$	B1 B1 B1 B1 M1 A1 A1 (7)
(b)	Since we need to maximise first subtract all entries from some $n \geq 41$ <table><tr><th></th><th>Task A</th><th>Task B</th><th>Task C</th></tr><tr><td>Worker P</td><td>8</td><td>4</td><td>10</td></tr><tr><td>Worker Q</td><td>9</td><td>5</td><td>1</td></tr><tr><td>Worker R</td><td>0</td><td>6</td><td>3</td></tr></table>	M1 A1 (2) **9**

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>(a)

(b)</td><td><u>Notes:</u>
1B1: defining variables
2B1: defining variables
3B1: minimise
4B1: cao
1M1: At least 3 equations, coefficients of 1. Accept inequalities here should be precisely 9 variables.
1A1: cao 3 equations correct accept slack variables if defined
2A1: cao 6 equations correct accept slack variables if defined

1M1: subtracting from some n ≥ 41 condone up to two errors
1A1: correct</td><td></td></tr>
<tr><td>7.
(a)</td><td>
<table>
<tr><th>Stage</th><th>State</th><th>Action</th><th>Dest.</th><th>Value</th></tr>
<tr><td>0</td><td>H</td><td>H- London</td><td>London</td><td>36 – 5 = 31*</td></tr>
<tr><td></td><td>I</td><td>I – London</td><td>London</td><td>38 – 4 = 34*</td></tr>
<tr><td>1</td><td>F</td><td>FH</td><td>H</td><td>29 – 6 + 31 = 54</td></tr>
<tr><td></td><td></td><td>FI</td><td>I</td><td>29 – 7 + 34 = 56*</td></tr>
<tr><td></td><td>G</td><td>GH</td><td>H</td><td>27 – 5 + 31 = 53</td></tr>
<tr><td></td><td></td><td>GI</td><td>I</td><td>27 – 6 + 34 = 55*</td></tr>
<tr><td>2</td><td>C</td><td>CF</td><td>F</td><td>42 – 6 + 56 = 92*</td></tr>
<tr><td></td><td></td><td>CG</td><td>G</td><td>42 – 5 + 55 = 92*</td></tr>
<tr><td></td><td>D</td><td>DF</td><td>F</td><td>41 – 6 + 56 = 91</td></tr>
<tr><td></td><td></td><td>DG</td><td>G</td><td>41 – 3 + 55 = 93*</td></tr>
<tr><td></td><td>E</td><td>EF</td><td>F</td><td>39 – 4 + 56 = 91*</td></tr>
<tr><td></td><td></td><td>EG</td><td>G</td><td>39 – 4 + 55 = 90</td></tr>
<tr><td>3</td><td>A</td><td>AC</td><td>C</td><td>22 – 5 + 92 = 109</td></tr>
<tr><td></td><td></td><td>AD</td><td>D</td><td>22 – 4 + 93 = 111*</td></tr>
<tr><td></td><td></td><td>AE</td><td>E</td><td>22 – 2 + 91 = 111*</td></tr>
<tr><td></td><td>B</td><td>BC</td><td>C</td><td>17 – 4 + 92 = 105</td></tr>
<tr><td></td><td></td><td>BD</td><td>D</td><td>17 – 4 + 93 = 106*</td></tr>
<tr><td></td><td></td><td>BE</td><td>E</td><td>17 – 3 + 91 = 105</td></tr>
<tr><td>4</td><td>London</td><td>London – A</td><td>A</td><td>-5 + 111 = 106*</td></tr>
<tr><td></td><td></td><td>London – B</td><td>B</td><td>-3 + 106 = 103</td></tr>
</table>
Optimal expected income is £10 600</td><td>1M1 1A1
(2)
2M1 2A1

3A1
(3)
3M1 4A1ft

5A1ft
(3)
4M1 6A1ft

7A1ft
(3)</td></tr>
<tr><td>(b)</td><td>Optimal schedules are:
London – A – D – G – I – London (or v.v.)
London – A – E – F – I – London (or v.v)</td><td>B1ft
B1
(2)
13</td></tr>
</table>

Question Number	Scheme	Marks
	Notes: **Throughout section (a):** • **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.**	
(a)	1M1: First stage completed. 1A1: CAO Penalise * errors only once in the question on the first occurrence 2M1: Second stage completed. Penalise reversed states here and at end. Bod if something in each cell. 2A1: Any 2 states correct. (Penalise * errors only once in the question). 3A1: All 3 states correct. (Penalise * errors only once in the question). 3M1: 3rd stage completed. Bod if something in each cell. 4A1ft: A or B state correct. (Penalise * errors only once in the question). 5A1ft: A and B states correct. (Penalise * errors only once in the question). 4M1: 4th stage completed. Bod if something in each cell. 6A1ft: Final, state correct. (Penalise * errors only once in the question). 7A1ft: CAO	
(b)	1B1ft: 1 route correct, consistent with their working penalise reversed states again here. Condone absence of London 2B1: both routes cao. London to London.	

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