

# Mark Scheme (Results)

Summer 2014

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

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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
  - $\square$  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)	<table border="1"> <thead> <tr> <th></th> <th>P</th> <th>Q</th> <th>R</th> <th>S</th> <th>Supply</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>11</td> <td>2</td> <td></td> <td></td> <td>13</td> </tr> <tr> <td>B</td> <td></td> <td>4</td> <td></td> <td></td> <td>4</td> </tr> <tr> <td>C</td> <td></td> <td>4</td> <td>8</td> <td></td> <td>12</td> </tr> <tr> <td>D</td> <td></td> <td></td> <td>3</td> <td>8</td> <td>11</td> </tr> <tr> <td>Demand</td> <td>11</td> <td>10</td> <td>11</td> <td>8</td> <td></td> </tr> </tbody> </table>		P	Q	R	S	Supply	A	11	2			13	B		4			4	C		4	8		12	D			3	8	11	Demand	11	10	11	8		B1 (1)													
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### Notes for Question 1

a1B1: CAO

b1M1: Finding 8 shadow costs.

b1A1: Shadow costs CAO.

b2M1: Finding the 5 missing improvement indices.

b2A1: Improvement indices CAO [Shadow costs: A(28), B(25), C(22), D(21), P(0), Q(4), R(7), S(13)].

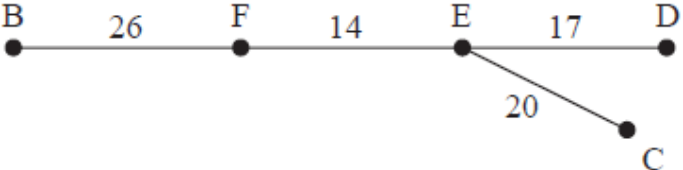
c1M1: A valid route, their most negative II chosen, only one empty square used,  $\theta$ 's balance.

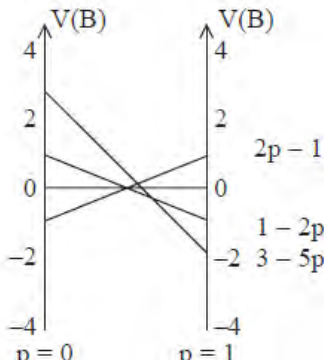
c1A1: CAO correct route.

c2A1ft: Correctly stating their entering and exiting cells.

c3A1: CSO

d1B1: CAO

Question Number	Scheme	Marks
2. (a)	In the practical problem each vertex must be visited at least once. In the classical problem each vertex must be visited just once.	B2, 1, 0 (2)
(b)	A D E F B C A $15 + 17 + 14 + 26 + 50 + 48 = 170$	M1 A1 A1 (3)
(c)	 <p>RMST weight = <math>26 + 14 + 17 + 20 = 77</math> (km)            Lower bound = <math>77 + 15 + 30 = 122</math> (km)</p>	M1 A1 A1 (3)
(d)	$122 \leq \text{length} \leq 170$	B2,1,0 (2)
<b>Notes for Question 2</b>		
<p>a1B1: Understands the difference is connected to the number of times each vertex may be visited.            a2DB1: Correctly identifies which is classical and which is practical and correctly states the difference.            b1M1: Nearest neighbour A – D – E – F – B – C – or accept 145623 across top of table (condone lack of return to start).            b1A1: Route correctly stated, must return to A, accept link back to A.            b2A1: Length correctly stated. Do not ISW if candidates then go on to double the route length.            c1M1: Finding RST (maybe implicit) and using the correct two least lengths. Their RST must have only four arcs of which none are incident to A.            c1A1: RMST correct <b>or</b> list of arcs <b>or</b> 77 <b>or</b> <math>26 + 14 + 17 + 20</math> seen.            c2A1: CAO 122            d1B1ft: Their correct numbers correctly used (their upper bound must be a cycle and their lower bound must have scored M1 in (c)), accept any inequalities or any indication of interval from their 122 to their 170.            d2B2: CAO including correct inequalities (but condone <math>122 &lt; \text{length} \leq 170</math>).</p>		

Question Number	Scheme	Marks											
3.(a)	Column 3 dominates column 1, so delete column 1	B1											
	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td></td> <td>B2</td> <td>B3</td> </tr> <tr> <td>A1</td> <td>2</td> <td>-3</td> </tr> <tr> <td>A2</td> <td>1</td> <td>-1</td> </tr> <tr> <td>A3</td> <td>-1</td> <td>1</td> </tr> </table> <p>Let B play 2 with probability <math>p</math> and 3 with probability <math>1-p</math>            If A plays 1 B's expected winnings are <math>-\{2p - 3(1-p)\} = 3 - 5p</math>            If A plays 2 B's expected winnings are <math>-\{p - (1-p)\} = 1 - 2p</math>            If A plays 3 B's expected winnings are <math>-\{-p + (1-p)\} = 2p - 1</math></p>  <p><math>2p - 1 = 1 - 2p</math>  <math>p = \frac{1}{2}</math></p> <p>B should play column 2 and column 3 each with probability <math>\frac{1}{2}</math> and never play column 1.</p>		B2	B3	A1	2	-3	A2	1	-1	A3	-1	1
	B2	B3											
A1	2	-3											
A2	1	-1											
A3	-1	1											
(b)	$V(B) = 0$	DM1 A1 A1 (9) B1 (1) <b>10 marks</b>											

### Notes for Question 3

a1B1: CAO Col 3 dominates Col 1

a2B1: Defines  $p$  – allow those who define B play 2 with prob.  $p$  but no incorrect statements.

a1M1: Setting up three probability equations, implicit definition of  $p$ .

a1A1: CAO (condone incorrect simplification).

a2M1: Three lines drawn, accept  $p > 1$  or  $p < 0$  here. Must be functions of  $p$ .

a2A1: CAO  $0 \leq p \leq 1$ , scale correct and clear (or 1 line = 1), condone lack of labels. Rulers used.

a3DM1: Must have drawn 3 lines. Finding their correct optimal point, must have three lines and set up an equation to find  $0 \leq p \leq 1$ . Dependent on previous M mark. Must have three intersection points. If solving each pair of SE's must clearly select the correct one or M0, but allow recovery if their choice is clear.

a3A1: CAO – dependent on all, but a2B1, being awarded in this part.

a4A1: CAO

bDB1: CAO – dependent on all previous M marks in (a).





Question Number	Scheme	Marks
5. (a)		M1 A1 A1 (3)
(b)		M1 A1 (2)
(c)	<p>E.g.  <math>SS_2BET_2T - 13</math>  <math>SS_2BADT_2T - 3</math>  <math>SS_2BADET_2T - 5</math></p>	M1 A1 A1 A1 (4)
(d)	<p>E.g.</p>	M1 A1 (2)
(e)	<p>The cut through <math>AT_1, DT_1, DT_2, DE, BE, CB</math> and <math>S_2C</math> has value 102          Value of the flow is 102 so by max flow – min cut theorem flow is maximal</p>	DB1 DB1 (2)

**13 marks**

**Notes for Question 5**

a1M1: Four arcs added,  $SS_1$ ,  $SS_2$ ,  $T_1T$ ,  $T_2T$  and 2 numbers on each.

a1A1: CAO for arcs

a2A1: CAO for flow values and capacities

b1M1: Two numbers on each arc and at least three arcs or six numbers correct.

b1A1: CAO do give bod since they might well cross these numbers out.

c1M1: One valid flow augmenting route found and a value stated.

c1A1: Flow increased by at least 3.

c2A1: A second correct flow route of value at least 5 and value correct.

c3A1: CSO Flow increased by 21 and no more.

d1M1: Consistent flow pattern  $\geq 84$  (check each node). One number only per arc. No unnumbered arcs.

d1A1: CAO, showing flow of 102, must follow from their routes.

e1DB1: Must have attempted (d) - at least one number on all but one arc, and made an attempt at a cut, either drawn or stated.

e2DB1: CSO - (d) fully correct (showing a correct flow of 102) and a correct cut. Must refer to max flow-min cut theorem – all four words.

Question Number	Scheme	Marks
6.	<p>Let <math>x_{ij}</math> be 0 or 1</p> $\begin{cases} 1 & \text{if worker } (i) \text{ does task } (j) \\ 0 & \text{otherwise} \end{cases}$ <p>where <math>i \in \{A, B, C, D\}</math> and <math>j \in \{1, 2, 3, 4\}</math></p> <p>minimise <math>C = 29x_{A1} + 15x_{A2} + 32x_{A3} + 30x_{A4}</math>  <math>+ 34x_{B1} + 26x_{B2} + 40x_{B3} + 32x_{B4}</math>  <math>+ 28x_{C1} + 27x_{C2} + 35x_{C3} + '100'x_{C4}</math>  <math>+ '100'x_{D1} + 21x_{D2} + 33x_{D3} + 31x_{D4}</math></p> <p>Subject to</p> $x_{A1} + x_{A2} + x_{A3} + x_{A4} = 1 \quad \text{or} \quad \sum x_{Aj} = 1$ $x_{B1} + x_{B2} + x_{B3} + x_{B4} = 1 \quad \text{or} \quad \sum x_{Bj} = 1$ $x_{C1} + x_{C2} + x_{C3} + x_{C4} = 1 \quad \text{or} \quad \sum x_{Cj} = 1$ $x_{D1} + x_{D2} + x_{D3} + x_{D4} = 1 \quad \text{or} \quad \sum x_{Dj} = 1$ $x_{A1} + x_{B1} + x_{C1} + x_{D1} = 1 \quad \text{or} \quad \sum x_{i1} = 1$ $x_{A2} + x_{B2} + x_{C2} + x_{D2} = 1 \quad \text{or} \quad \sum x_{i2} = 1$ $x_{A3} + x_{B3} + x_{C3} + x_{D3} = 1 \quad \text{or} \quad \sum x_{i3} = 1$ $x_{A4} + x_{B4} + x_{C4} + x_{D4} = 1 \quad \text{or} \quad \sum x_{i4} = 1$	<p>B1</p> <p>M1 A1</p> <p>M1</p> <p>A1 M1</p> <p>A1 <b>7 marks</b></p>
<b>Notes for Question 6</b>		
<p>1B1: Defining variables fully both ‘bits’ values and subscripts. Penalise poor variable choice, (AP etc.) here.  1M1: Attempt at a 16 term expression, coefficients ‘correct’, 2 ‘large’ values included, condone 2 slips.  1A1: CAO + minimise. Penalise reversed subscripts once only per question.  2M1: Four equations, each in four variables, unit coefficients, all 16 variables included, = 1, accept <math>\leq 1, \geq 1</math> here for this M only  2A1: Any 4 CAO.  3M1: All 8 equations, each in four variables, unit coefficients, all 16 variables included = 1.  3A1: CAO.</p>		

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<b>7. (a)</b>	E.g.																																																																																																																																			
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	Bicycle	4	4	0	350																																																																																																																															
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		2	2	0	170																																																																																																																															
		1	1	0	80																																																																																																																															
		(0	0	0	0)																																																																																																																															
	Dolls	4	0	4	$0 + 350 = 350$																																																																																																																															
	house		1	3	$95 + 260 = 355^*$																																																																																																																															
			2	2	$165 + 170 = 335$																																																																																																																															
			3	1	$245 + 80 = 325$																																																																																																																															
			4	0	$335 + 0 = 335$																																																																																																																															
		3	0	3	$0 + 260 = 260$																																																																																																																															
			1	2	$95 + 170 = 265^*$																																																																																																																															
			2	1	$165 + 80 = 245$																																																																																																																															
			3	0	$245 + 0 = 245$																																																																																																																															
		2	0	2	$0 + 170 = 170$																																																																																																																															
			1	1	$95 + 80 = 175^*$																																																																																																																															
			2	0	$165 + 0 = 165$																																																																																																																															
		1	0	1	$0 + 80 = 80$																																																																																																																															
			1	0	$95 + 0 = 95^*$																																																																																																																															
		(0	0	0	$0 + 0 = 0$ )																																																																																																																															
	Train	4	0	4	$0 + 355 = 355$																																																																																																																															
	set		1	3	$100 + 265 = 365^*$																																																																																																																															
			2	2	$180 + 175 = 355$																																																																																																																															
			3	1	$260 + 95 = 355$																																																																																																																															
		4	0	$340 + 0 = 340$																																																																																																																																
<b>(b)</b>	<table border="1"> <thead> <tr> <th>Toy</th> <th>Bicycle</th> <th>Dolls House</th> <th>Train Set</th> </tr> </thead> <tbody> <tr> <td>Number of workers</td> <td>2</td> <td>1</td> <td>1</td> </tr> </tbody> </table>	Toy	Bicycle	Dolls House	Train Set	Number of workers	2	1	1	1B1 (1)																																																																																																																										
	Toy	Bicycle	Dolls House	Train Set																																																																																																																																
Number of workers	2	1	1																																																																																																																																	
	Total number of toys is 365.	1B1 (1)																																																																																																																																		
		<b>13 marks</b>																																																																																																																																		

### Notes for Question 7

- **ALL M marks - Must bring earlier optimal results into calculations. Ignore extra rows. Must have right 'ingredients' (– number of workers) at least once per stage.**
- **Penalise inconsistency/errors with the state/destination columns with the first two A marks earned only.**
- **Penalise empty/errors in stage column with first A mark earned only.**

a1M1: First stage (Bicycle) completed – bod something in each cell. Must have columns for stage, state, value and one of either action or destination.

a1A1: CAO condone missing \* here. Condone missing zero row.

a2M1: Second stage (Dolls house) completed for at least states 4 and 3. Bod something in each cell.

a2A1: Any one of these states correct. No missing rows. (Penalise \* errors only once in the question).

a3A1: CAO both states 4 and 3 correct. No missing rows. (Penalise \* errors only once in the question).

a3M1: Second stage (Dolls house) fully completed, condone missing zero row. Bod something in each cell.

a4A1: States 2 and 1 correct. No missing rows. (Penalise \* errors only once in the question).

a5A1: CAO for stage 2. No missing rows. (Penalise \* errors only once in the question).

a4M1: Third stage (Train set) completed. Bod something in each cell.

a6A1ft: Any three rows of third stage correct. Ft on \* values only. No missing rows. (Penalise \* errors only once in the question).

a7A1: CAO for the third stage. No missing rows. (Penalise \* errors only once in the question).

a1B1: CAO. Must have attempted algorithm, getting all previous M marks.

b1B1: CAO. Must have attempted algorithm, getting all M marks in (a).

