edexcel

Mark Scheme (Results)

Summer 2014

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

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Summer 2014
Publications Code UA038495

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)		B1 **(1)**
(b)		M1 A1 M1 A1 **(4)**
(c)	Entering square AS Exiting square is AQ, ($\theta = 2$).	M1 A1 A1ft
(d)	Current cost = £1152	A1 **(4)** B1 **(1)** **10 marks**

	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	

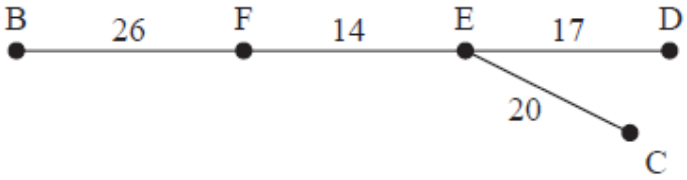
Shadow costs		**28**	**32**	**35**	**41**	
		P	Q	R	S	Supply
0	A	x	x	**-2**	**-14**	13
- 3	B	6	x	**-6**	**-7**	4
-6	C	8	x	x	**-3**	12
-7	D	4	5	x	x	11
	Demand	11	10	11	8	

	P	Q	R	S	Supply
A	11	$2 - \theta$		θ	13
B		4			4
C		$4 + \theta$	$8 - \theta$		12
D			$3 + \theta$	$8 - \theta$	11
Demand	11	10	11	8	

	P	Q	R	S	Supply
A	11			2	13
B		4			4
C		6	6		12
D			5	6	11
Demand	11	10	11	8	70

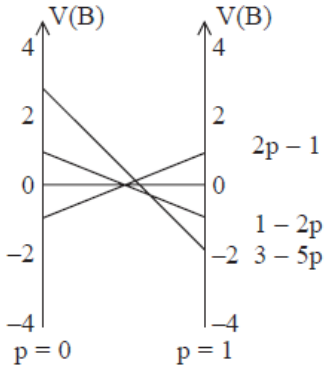
Notes for Question 1

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, θ'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)	 RMST weight = 26 + 14 + 17 + 20 = 77 (km) Lower bound = 77 + 15 + 30 = 122 (km)	M1 A1 A1 **(3)**
(d)	122 ≤ length ≤ 170	B2,1,0 **(2)** **10 marks**

Notes for Question 2

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 **or** list of arcs **or** 77 **or** 26 + 14 + 17 + 20 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 122 < length ≤ 170).

Question Number	Scheme	Marks
3.(a)	Column 3 dominates column 1, so delete column 1	B1
	<table><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>	
	Let B play 2 with probability p and 3 with probability $1-p$	B1
	If A plays 1 B's expected winnings are $-\{2p-3(1-p)\} = 3-5p$ If A plays 2 B's expected winnings are $-\{p-(1-p)\} = 1-2p$ If A plays 3 B's expected winnings are $-\{-p+(1-p)\} = 2p-1$	M1 A1
		M1 A1
	$2p-1 = 1-2p$	DM1
	$p = \frac{1}{2}$	A1
	B should play column 2 and column 3 each with probability $\frac{1}{2}$ and never play column 1.	A1 **(9)**
(b)	V(B) = 0	B1 **(1)**
		10 marks

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 $0 \le p \le 1$, 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 $0 \le p \le 1$. 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
4.(a)		

b.v	x	y	z	r	s	t	value	θ values
r	4	3	$\frac{5}{2}$	1	0	0	50	16.67
s	1	2	1	0	1	0	30	15
t	0	5	1	0	0	1	80	16
P	–25	–40	–35	0	0	0	0	

b.v.	x	y	z	r	s	t	value	Row ops
r	$\frac{5}{2}$	0	1	1	$-\frac{3}{2}$	0	5	R1 – 3R2
y	$\frac{1}{2}$	1	$\frac{1}{2}$	0	$\frac{1}{2}$	0	15	R2 ÷ 2
t	$-\frac{5}{2}$	0	$-\frac{3}{2}$	0	$-\frac{5}{2}$	1	5	R3 – 5R2
P	–5	0	–15	0	20	0	600	R4 + 40R2

M1 A1
B1
M1 A1

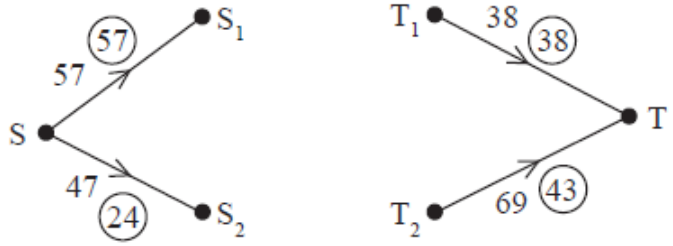
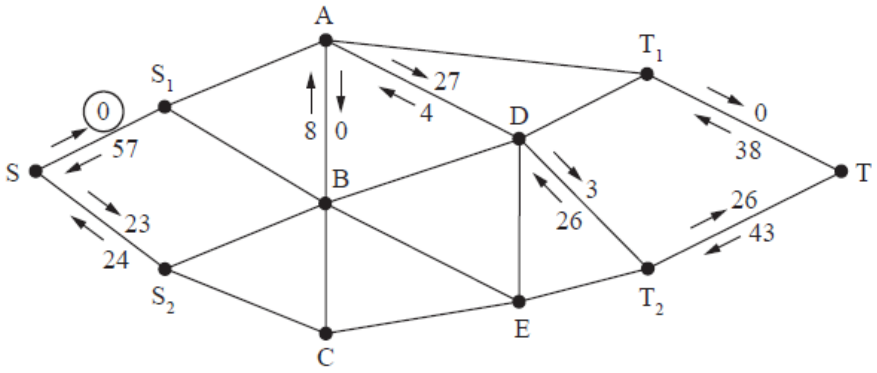
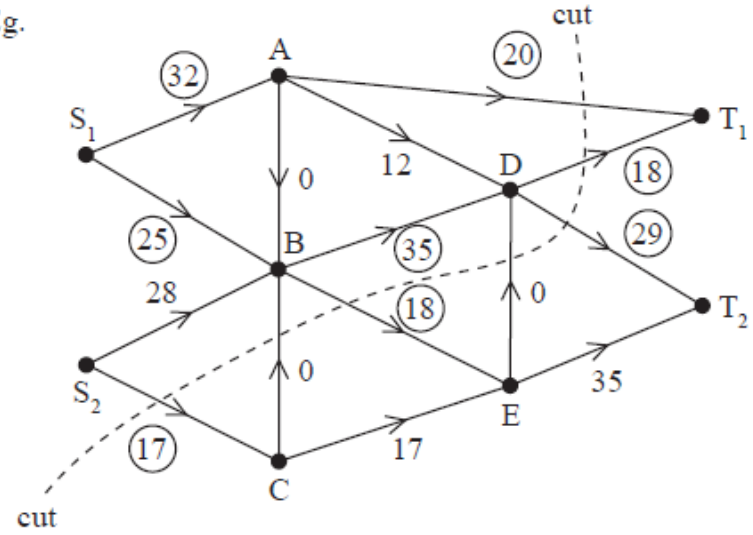
b.v.	x	y	z	r	s	t	value	Row ops
z	$\frac{5}{2}$	0	1	1	$-\frac{3}{2}$	0	5	R1stet
y	$-\frac{3}{4}$	1	0	$-\frac{1}{2}$	$\frac{5}{4}$	0	12.5	R2 – $\frac{1}{2}$R1
t	$\frac{5}{4}$	0	0	$\frac{3}{2}$	$-\frac{19}{4}$	1	12.5	R3 + $\frac{3}{2}$R1
P	32.5	0	0	15	–2.5	0	675	R4 + 15R1

B1
B1
M1 A1 **(9)**

(b)	$P + 32.5x + 15r – 2.5s = 675$	B1 **(1)**
(c)	$P = 675 – 32.5x – 15r + 2.5s$, so can increase profit by increasing s, hence not optimal.	B2,1,0 **(2)**
		12 marks

Notes for Question 4

a1M1: Correct pivot located, attempt to divide row. If choosing negative pivot no marks.
a1A1: Pivot row correct including change of b.v.
a1B1: Row operations CAO – allow if given in terms of old row 2.
a2M1: (ft) Correct row operations used at least once, column x, z, s or value correct.
a2A1: CAO on numbers (ignore row operations and b.v.).
a2B1: Correct pivot located and b.v. changed. If choosing negative pivot 2B0 3M0.
a3B1: Row operations CAO.
a3M1: (ft) Correct row operations used at least once, column x, r, s or value correct.
a3A1: CAO on numbers (ignore row operations and b.v.).
b1B1: CAO
c1B1ft: **Explanation**. Must have gained at least 2 M marks in (a) must refer to increasing x, r and s, (condone no ref to $y = z = t = 0$), must have correct signs in equation in (b). Do not accept 'negatives in profit row' o.e. alone.
c2DB1: CAO – dependent on correct equation in (b). Specifically identifies s as the next variable that could be increased.

Question Number	Scheme	Marks
5. (a)		M1 A1 A1 **(3)**
(b)		M1 A1 **(2)**
(c)	E.g. SS_2BET_2T – 13 SS_2BADT_2T – 3 SS_2BADET_2T – 5	M1 A1 A1 A1 **(4)**
(d)	Eg. 	M1 A1 **(2)**
(e)	The cut through AT_1, DT_1, DT_2, DE, BE, CB and S_2C has value 102 Value of the flow is 102 so by max flow – min cut theorem flow is maximal	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 ≥ 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.	Let x_{ij} be 0 or 1 $\begin{cases}1 \text{ if worker } (i) \text{ does task } (j)\\ 0 \text{ otherwise}\end{cases}$ where $i \in \{\text{A, B, C, D}\}$ and $j \in \{1, 2, 3, 4\}$ minimise $C = 29x_{A1} + 15x_{A2} + 32x_{A3} + 30x_{A4}$ $+ 34x_{B1} + 26x_{B2} + 40x_{B3} + 32x_{B4}$ $+ 28x_{C1} + 27x_{C2} + 35x_{C3} + '100'x_{C4}$ $+ '100'x_{D1} + 21x_{D2} + 33x_{D3} + 31x_{D4}$ Subject to $x_{A1} + x_{A2} + x_{A3} + x_{A4} = 1$ or $\sum x_{Aj} = 1$ $x_{B1} + x_{B2} + x_{B3} + x_{B4} = 1$ or $\sum x_{Bj} = 1$ $x_{C1} + x_{C2} + x_{C3} + x_{C4} = 1$ or $\sum x_{Cj} = 1$ $x_{D1} + x_{D2} + x_{D3} + x_{D4} = 1$ or $\sum x_{Dj} = 1$ $x_{A1} + x_{B1} + x_{C1} + x_{D1} = 1$ or $\sum x_{i1} = 1$ $x_{A2} + x_{B2} + x_{C2} + x_{D2} = 1$ or $\sum x_{i2} = 1$ $x_{A3} + x_{B3} + x_{C3} + x_{D3} = 1$ or $\sum x_{i3} = 1$ $x_{A4} + x_{B4} + x_{C4} + x_{D4} = 1$ or $\sum x_{i4} = 1$	B1 M1 A1 M1 A1 M1 A1 **7 marks**

Notes for Question 6

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 $\leq 1, \geq 1$ 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.

Question Number	Scheme	Marks
7. (a)	E.g.	

Stage	State	Action	Dest	Value	Marks
Bicycle	4	4	0	350	1M1 1A1 **(2)**
	3	3	0	260	
	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*	2M1 2A1 3A1 **(3)**
		2	2	165 + 170 = 335	
		3	1	245 + 80 = 325	States 4 + 3
		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	3M1 4A1 5A1 **(3)**
		1	1	95 + 80 = 175*	
		2	0	165 + 0 = 165	States 2 + 1
	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*	4M1 6A1ft 7A1 **(3)**
		2	2	180 + 175 = 355	
		3	1	260 + 95 = 355	
		4	0	340 + 0 = 340	

Toy	Bicycle	Dolls House	Train Set	
Number of workers	2	1	1	1B1 **(1)**

(b) Total number of toys is 365. 1B1 **(1)**

13 marks

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).

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