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Mark Scheme (Results)

Summer 2013

GCE Decision Mathematics 2 (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
- ⌐ 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.

8. In some instances, the mark distributions (e.g. M1, B1 and A1) printed on the candidate's response may differ from the final mark scheme.

Question Number	Scheme	Marks
1.(a)	Subtracting all elements from some n ≥228	1M1
	Reducing rows and then columns to get	2M1
	0 11 16 14 / 0 17 20 17 / 0 17 18 16 / 0 16 25 18 then 0 0 0 0 / 0 6 4 3 / 0 6 2 2 / 0 5 9 4	1A1
	Using two lines and 2 to get	3M1
	2 0 0 0 / 0 4 2 1 / 0 4 0 0 / 0 3 7 2	2A1
	Using three lines and 1 to get	4M1
	3 0* 0 0 / 0 3 1 0* / 1 4 0* 0 / 0* 2 6 1	3A1ft 4A1 **(8)**
(b)	So C = 2, J = 4, K = 3 and N = 1	M1
	maximum profit of £664	A1 **(2)** **10 marks**
	Note ' minimise' gives this special case	
	0 4 0 0 / 4 2 0 1 / 2 0 0 0 / 9 8 0 4 then 0* 4 1 0 / 3 1 0 0* / 2 0* 1 0 / 8 7 0* 3 then C = 1, J = 4, K = 2, N = 3 Profit £651	
	Gives 5 max: (a) 1M0 2M1 1A1 3M0 2A0 4M1 3A1ft 4A0 (b) M1A0	

Notes for Question 1

a1M1: Subtracting all elements from some $n \geq 228$, condone up to 2 errors
a2M1: Reducing rows **and then** columns
a1A1: CAO
a3M1: Double covered +e; one uncovered – e; and one single covered unchanged. 2 lines needed to 3 lines needed.
a2A1: CAO
a4M1: One double covered +e; one uncovered – e; and one single covered unchanged. 3 lines needed to 4 lines needed.
a3A1ft: on their previous table.
a4A1: CSO on final table
b1M1: Their optimal allocation (of workers to tasks) and an attempt to calculate the profit – this mark is dependent on all M marks in (a) have been earned.
b1A1: CAO

Question Number	Scheme	Marks
2.(a)	E.g. If use CD as shortcut get 807 or if use CF + AD get 793	M1 A1 **(2)**
(b)	A F E D B C A 82 113 98 130 110 217 = 750	B1 B1 **(2)**
(c)	length of RMST = 439 439 + 82 + 113 = 634	B1 M1 A1 **(3)**
(d)	634 < optimal $\leq$750	B1ft **(1)** **8 marks**

Notes for Question 2

a1M1: Their plausible shortcut leading to a value < 810 and a length below 810 stated.
a1A1: CAO – shortcut and length must be consistent.

(Examples shortcuts: CD = 807, CF + AD = 793, CF + BD = 664, AD + EF + FC = 715, DF + FC = 785 etc.)

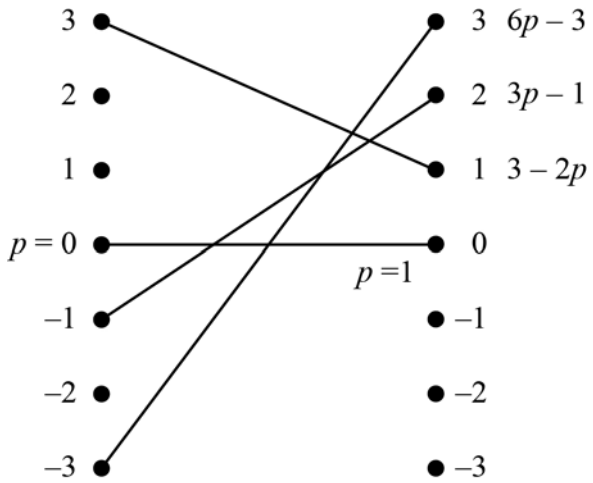
b1B1: CAO
b2B1: CAO
c1B1: CAO
c1M1: Adding two least weighted arcs to their RMST length
c1A1: CAO
d1B1: An interval that incorporates their lower bound from (c) and their best upper bound from either (a) or (b)

Question Number	Scheme	Marks
3.(a)	The solution would otherwise be **degenerate**	B1 **(1)**
(b)	22 36 31 46 **1 2 3 4** 0 **A** x x -12 -9 -1 **B** 8 x x -9 -6 **C** (8) (2) x (1) -8 **D** (9) (2) x x	M1 A1 M1 A1 **(4)**
(c)	Route is e.g. A3 – B3 – B2 – A2 entering cell A3, Exiting cell B3	M1 A1 A1 **(3)**
		8 marks

Notes for Question 3

a1B1: CAO
b1M1: 8 shadow costs stated.
b1A1: CAO
b2M1: Remaining 4 IIs stated.
b2A1: CAO
c1M1: A valid route (possibly drawn), their most negative II chosen, only one empty square used, θ's balance.
c1A1: CAO – stepping stone route **stated** or clearly shown on **separate** diagrams
c2A1: CAO for entering and exiting cells.

(b) Alternative shadow costs:
1(0) 2(14) 3(9) 4(24)
A(22) B(21) C(16) D(14)

Question Number	Scheme	Marks
4.	R1 dominates R2, so deleted R2 to give 2 1 3 -1 3 -3 If S plays 1; R's gain is 2p – (1 – p) = 3p – 1 If S plays 2; R's gain is p + 3(1 – p) = 3 – 2p If S plays 3; R's gain is 3p – 3(1 – p) = 6p – 3  3 – 2p = 3p – 1 giving p = 4/5 Robin should play R1 with probability 4/5 R2 never R3 with probability 1/5 The value of the game is 7/5 to Robin	B1 M1 A1 B1ft B1 M1 A1 A1ft A1 **9 marks**

Notes for Question 4

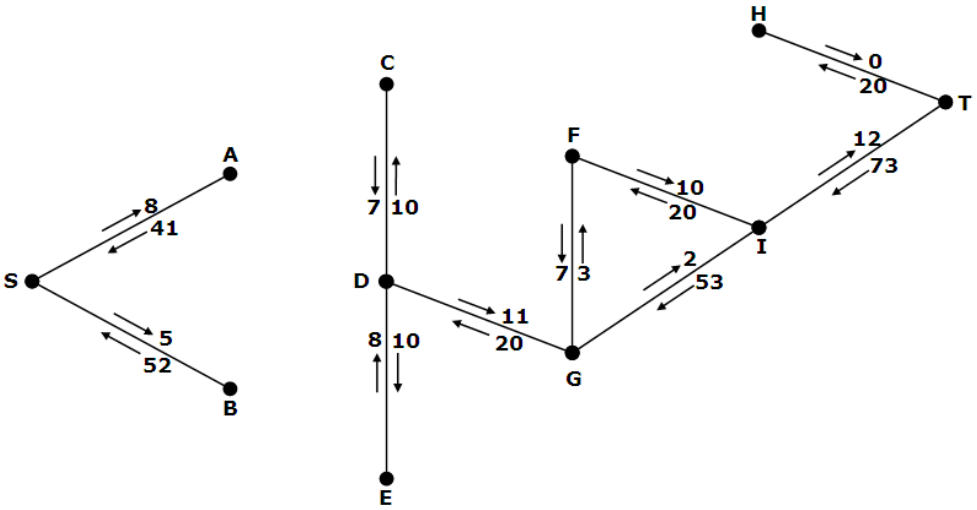
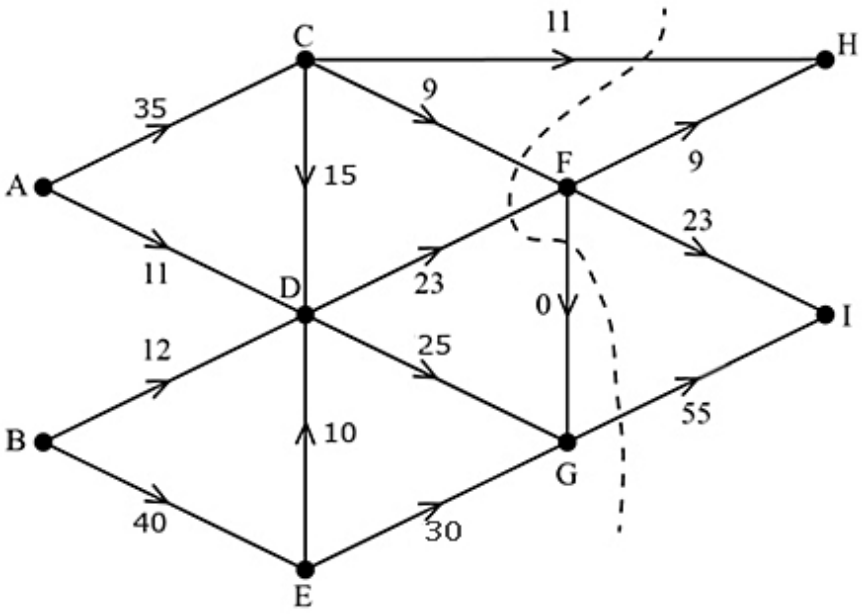
1B1: CAO
1M1: Setting up three probability expressions, implicit definition of 'p'.
1A1: CAO (condone incorrect simplification)
2B1ft: Attempt at three lines (correct gradients and correct order of intersection with 'axes'), accept p > 1 or p < 0 here. Must be functions of p.
3B1: CAO 0 ≤ p ≤ 1, scale clear (or 1 line = 1), condone lack of labels. Rulers used.
2M1: Finding their correct optimal point, must have three lines and three intersection points and set up an equation to find 0 ≤ p ≤ 1. Dependent on the second B mark being earned. Solving all three simultaneous equations only is M0.
2A1: CSO (all previous marks must have been awarded)
3A1ft: All three options listed must ft from their p, check page 1 for R should never play 2. $0 \leq \text{probabilities} \leq 1$ Dependent on **both** previous M marks being awarded.
4A1: CAO for the value of the game (7/5)

Question Number	Scheme	Marks
5. (a)		M1 A1 M1 A1 A1 **(5)**
(b)	$P + x + 4s + 18t = 240$	B1 **(1)**
(c)	$P = 240 - x - 4s - 18t$ and at present x, s and t are zero. If we increase any of these the profit will decrease.	B2, 1, 0 **(2)**
		8 marks

b.v.	*x*	*y*	*z*	*r*	*s*	*t*	Value	Row ops
r	$\frac{4}{5}$	0	0	1	$\frac{1}{5}$	$-\frac{3}{5}$	11	$R_1 + \frac{1}{2}R_2$
y	$\frac{3}{5}$	1	0	0	$\frac{2}{5}$	$-\frac{1}{5}$	2	$R_2 \div 2.5$
z	$\frac{1}{5}$	0	1	0	$-\frac{1}{5}$	$\frac{3}{5}$	4	$R_3 - \frac{1}{2}R_2$
P	1	0	0	0	4	18	240	$R_4 + 10R_2$

Notes for Question 5

a1M1: correct pivot located, attempt to divide row. If choosing negative pivot M0M0.
a1A1: pivot row correct including change of b.v.
a2M1: (ft) One row (excluding the pivot row) correct or one column either the value, *x*, *s* or *t* column correct.
a2A1ft: Correct row operations used at least once. One column either the value, *x*, *s* or *t* column correct on the ft.
a3A1: CAO.
b1B1: CAO
c1B1: Using their profit equation to make a pertinent statement. Maybe muddled, if bod give this mark only. No 'negatives' in their profit equation.
c2B1: Good explanation – dependent on the correct equation being stated in (b).

Question Number	Scheme	Marks
6.(a)	Initial flow = 93	B1 **(1)**
(b)	Adds supersource S plus arcs SA(49) and SB(57) Adds supersink T plus arcs HT(20) and IT(85)	M1 A1 **(2)**
		M1 A1 A1 **(3)**
(d)	E.g. SACDGIT – 2 and SACDGFIT - 3 Maximum flow = 98	M1 A1 A1 **(3)**
(e)	E.g. 	M1 A1 **(2)**
(f)	Max flow= min cut, cut through CH, CF, DF, FG, GI	M1 A1 **(2)**

Question Number	Scheme	Marks
		13 marks

Notes for Question 5

a1B1: CAO
b1M1: All relevant arcs added OR all arcs and numbers from supersource OR from supersink correct.
b1A1: CAO all arcs and numbers correct.
c1M1: 2 numbers and arrows on each arc.
c1A1: CAO Condone 4 errors.
c2A1: CAO.
d1M1: One valid flow augmenting route (from S to T) found and a value stated.
d1A1: Flow increased by 5 and no more.
d2A1: CAO 98 (allow if seen in (f) but must be clearly labelled as the maximum flow)
e1M1: Consistent flow pattern > 95 – condone S and T's presence. Must have exactly one number on each arc.
e1A1: CAO must follow from their routes (allow if routes in (d) do not include S and/or T).
f1M1: Must have attempted (e) and made an attempt at a cut.
f1A1: cut correct – may be drawn. Must have shown a correct flow of 98 in (e). Refer to max flow-min cut theorem all four words.

Examples of flow augmenting routes:

- SACDGFIT (3), SACDGIT (2)
- SBEDGFIT (3), SBEDGIT (2)
- SBEDGFIT (3), SACDGIT (2)
- SACDGFIT (3), SBEDGIT (2)

Question Number	Scheme	Marks
7.	E.g. Add 4 to each element	B1
	Let p_1, p_2, p_3 be the probability of (A) playing 1, 2 and 3 respectively (where p_1, p_2, $p_3 \geq 0$)	B1
	let V = value of the game (to player A)	B1
	maximise P = V	B1
	subject to: $5p_1 + 2p_2 + 9p_3 \geq V$ $p_1 + 7p_2 + 3p_3 \geq V$ $6p_1 + 3p_2 + 4p_3 \geq V$	M1 A1
	$p_1 + p_2 + p_3 \leq 1$	A1 **(7)** **7 marks**

Notes for Question 7

1B1: Making all terms non-negative.
2B1: Defining probability variables
3B1: Defining V
4B1: 'maximise' + function/expression
1M1:At least three equations/inequations in (V), p_1, p_2 and p_3
1A1: The three inequalities in V, p_1, p_2 and p_3 CAO
1A1: probability sum inequality (or equation) correct.

Question Number	Scheme					Marks
8.	Stage	State	Action	Dest.	Value	
	Fresh	0	0	0	0	
		1	1	0	45	
		2	2	0	85	1M1 1A1
		3	3	0	120	(stage 1)
		4	4	0	150	
		5	5	0	175	
	Frozen	0	0	0	0	
		1	1	0	45 + 0 = 45*	
			0	1	0 + 45 = 45*	
		2	2	0	70 + 0 = 70	
			1	1	45 + 45 = 90*	2M1 2A1
			0	2	0 + 85 = 85	(1^{st} 4 states of
		3	3	0	100 + 0 = 100	stage 2)
			2	1	70 + 45 = 115	
			1	2	45 + 85 = 130*	3A1
			0	3	0 + 120 = 120	(state 3)
		4	4	0	120 + 0 = 120	
			3	1	100 + 45 =145	
			2	2	70 + 85 = 155	3M1 4A1
			1	3	45 + 120 = 165*	(Last 2 states
			0	4	0 + 150 = 150	of stage 2)
		5	5	0	130 + 0 = 130	
			4	1	120 + 45 = 165	
			3	2	100 + 85 = 185	
			2	3	70 + 120 = 190	5A1
			1	4	45 + 150 = 195*	(state 5)
			0	5	0 + 175 = 175	
	Canned	5	5	0	195 + 0 = 195	
			4	1	155 + 45 = 200	
			3	2	125 + 90 = 215*	4M1 6A1ft
			2	3	75 + 130 = 205	(3^{rd} stage)
			1	4	35 + 165 = 200	
			0	5	0 + 195 = 195	
	Fresh = 1, Frozen = 1, Canned = 3 Monthly income = £ 21 500					5M1 7A1ft **12 marks**

Notes for Question 8

- **ALL M marks - Must bring earlier optimal results into calculations. Must have necessary right 'ingredients' (profit values from the table) 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.**

1M1: First stage completed (bod something in each cell). Condone missing state 0 for this mark. Must have columns for stage, state, value and one of either action or destination.
1A1: CAO for first stage – condone missing * in this stage.
2M1: Second stage – states 0, 1 and 2 complete (bod something in each cell). Condone missing state 0 for this mark.
2A1: States 0, 1 and 2 correct for second stage. Penalise * errors only twice in the question on the first occurrences.
3A1: State 3 correct for second stage. Penalise * errors only twice in the question.
3M1: Second stage – states 3 and 4 complete (bod something in each cell).
4A1: State 4 correct for second stage. Penalise * errors only twice in the question.
5A1: State 5 correct for second stage. Penalise * errors only twice in the question.
4M1: Third stage complete (bod something in each cell).
6A1ft: Third stage correct (ft from previous stage). Penalise * errors only twice in the question.
5M1: For Fresh = 1, Frozen = 1, Canned = 3 – dependent on all previous M marks having been awarded.
7A1ft: Income correct for their table. Must have earned the first 4 M marks only (**not** dependent on 5M1).

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