Mark Scheme

Mock Paper Set 2

Pearson Edexcel GCE Further Mathematics

Decision Mathematics 1 Paper 9FM0_3D

Mock paper
Publications Code 9FM0_3D_Mock paper_MS

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.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- 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 √ 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. 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.

5. Where a candidate has made multiple responses <u>and indicates which response they wish to submit</u>, examiners should mark this response.
   If there are several attempts at a question <u>which have not been crossed out</u>, examiners should mark the final answer which is the answer that is the <u>most complete</u>.

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

7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

General Principles for Core Mathematics Marking

(*But note that specific mark schemes may sometimes override these general principles*)

Method mark for solving 3 term quadratic:

1. Factorisation

$(x^2 + bx + c) = (x + p)(x + q),$ where $|pq| = |c|$, leading to $x = \ldots$

$(ax^2 + bx + c) = (mx + p)(nx + q),$ where $|pq| = |c|$ and $|mn| = |a|$, leading to $x = \ldots$

2. Formula

Attempt to use the correct formula (with values for *a*, *b* and *c*)

3. Completing the square

Solving $x^2 + bx + c = 0$: $\left(x \pm \frac{b}{2}\right)^2 \pm q \pm c = 0, \quad q \neq 0$, leading to $x = \ldots$

Method marks for differentiation and integration:

1. Differentiation

Power of at least one term decreased by 1. $(x^n \rightarrow x^{n-1})$

2. Integration

Power of at least one term increased by 1. $(x^n \rightarrow x^{n+1})$

Use of a formula

Where a method involves using a formula that has been learnt, the advice given in recent examiners' reports is that the formula should be quoted first.

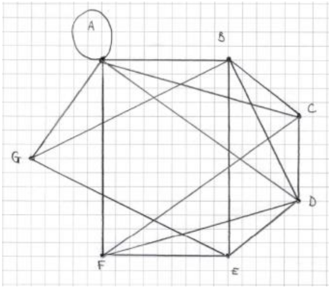
Normal marking procedure is as follows:

Method mark for quoting a correct formula and attempting to use it, even if there are small errors in the substitution of values.

Where the formula is not quoted, the method mark can be gained by implication from correct working with values but may be lost if there is any mistake in the working.

Exact answers

Examiners' reports have emphasised that where, for example, an exact answer is asked for, or working with surds is clearly required, marks will normally be lost if the candidate resorts to using rounded decimals.

<table>
<tr><th>Question</th><th>Scheme</th><th>Marks</th><th>AOs</th></tr>
<tr><td>1. (a)</td><td>Two graphs are isomorphic when they contain the same number of vertices of the same degree connected in the same way.</td><td>B1</td><td>1.2</td></tr>
<tr><td></td><td></td><td>(1)</td><td></td></tr>
<tr><td>(b)</td><td>E.g.
 </td><td>M1
A1</td><td>1.1b
1.1b</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td>(c)</td><td>Column (or row) totals for adjacency matrix are: 7, 5, 4, 5, 4, 4, 3
Graph is neither as there are more than two nodes of odd degree.</td><td>M1
A1</td><td>1.1b
2.4</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td>(d)</td><td>E.g.
Hamiltonian cycle: A B C D F E G A
(graph redrawn with Hamiltonian cycle as vertices of polygon).
<table>
<tr><td>List 1</td><td>List 2</td></tr>
<tr><td>AC</td><td>BG</td></tr>
<tr><td></td><td>BE</td></tr>
<tr><td></td><td>BD</td></tr>
<tr><td>AD</td><td></td></tr>
<tr><td>AF</td><td></td></tr>
</table>
CF crosses AD and BD which are in separate lists so graph is not planar</td><td>B1
M1
M1
A1</td><td>1.1b
2.1
1.1b
2.4</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td colspan="4">Total: 9 marks</td></tr>
</table>

Notes

a1B1	CAO
b1M1	Correct arcs drawn – allow one error (one incorrect arc, one missing arc, one extra arc).
b1A1	CAO
c1M1	Attempt to sum columns or rows or to list the degree of each node or to identify >2 nodes of odd degree
c1A1	Correct conclusion and reason.
d1B1	Any correct Hamiltonian cycle – must contain 8 vertices, start and finish at the same node and every vertex must appear only once except the start and end vertex.
d1M1	Creates two lists of arcs (with at least three arcs in each list)
d2M1	One arc identified as crossing arcs in both lists
d1A1	CAO including correct conclusion.

<table>
<tr><th>Question</th><th>Scheme</th><th>Marks</th><th>AOs</th></tr>
<tr><td>2. (a)</td><td>Sum of lengths = $40 + n$
$40 + n > 13 \times 4$
$n > 12$ so $12 < n \leq 13$</td><td>M1

A1</td><td>1.1b

2.2a</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td>(b)</td><td><table>
<tr><td>7</td><td>3</td><td>12</td><td>9</td><td>n</td><td>4</td><td>5</td></tr>
<tr><td>7</td><td>12</td><td>9</td><td>n</td><td>4</td><td>5</td><td>3</td></tr>
<tr><td>12</td><td>9</td><td>n</td><td>7</td><td>5</td><td>4</td><td>3</td></tr>
<tr><td>12</td><td>n</td><td>9</td><td>7</td><td>5</td><td>4</td><td>3</td></tr>
<tr><td>n</td><td>12</td><td>9</td><td>7</td><td>5</td><td>4</td><td>3</td></tr>
<tr><td>n</td><td>12</td><td>9</td><td>7</td><td>5</td><td>4</td><td>3</td></tr>
</table>
No change in final pass so list is sorted.</td><td>M1
A1
A1ft
A1</td><td>1.1b
1.1b
1.1b
1.1b</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td>(c)</td><td>Bin 1: $\underline{n}$
Bin 2: $\underline{12}$
Bin 3: $\underline{9}$ 4
Bin 4: $\underline{7}$ $\underline{5}$
Bin 5: 3</td><td>M1
A1</td><td>1.1b
1.1b</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td>(d)</td><td>Wasted wood = $25 – n$
Income from re-sale of wasted wood = $0.8(25 – n)$
Cost of wood planks = $5 \times 32 = 160$
Resulting wood expense = ‘160’ – ‘$0.8(25 – n)$’ = $140 + 0.8n$
$140 + 0.8n = 150.16$
$n = 12.7$</td><td>
M1

M1
A1</td><td>
2.1

2.1
2.2a</td></tr>
<tr><td></td><td></td><td>(3)</td><td></td></tr>
<tr><td colspan="4">Total: 11 marks</td></tr>
</table>

Notes

a1M1	Use of sum of lengths in a lower bound calculation involving 4
a1A1	CAO
b1M1	Bubble sort, consistent direction, 3 in place
b1A1	1st and 2nd passes correct
b2A1ft	3rd and 4th passes correct
b3A1	CSO including either ‘sort complete’ statement or 5th pass.
c1M1	n, 12, 9, 7, 5 placed correctly
c1A1	CAO
d1M1	Calculation of income from wasted wood in terms of n
d2M1	Determines resulting wood expense in terms of n and equates to 150.16
d1A1	CAO

Question	**Scheme**	**Marks**	**Aos**
3. (a)	A Hamiltonian cycle is a closed path that passes through every vertex exactly once, returning to the start vertex.	B1	1.2
		(1)	
(b)	$3 + 5 + 3 + 6 + 4 + 7.5 = 28.5$ Upper bound = 28.5	B1	1.1b
		(1)	
(c)(i) **(ii)**	A C E F B D A **and** A C B D F E A Upper bounds are $21 + d$ and 26 respectively	B1 B1	1.1b 1.1b
		(2)	
(d)	e.g. RMST: AD AC BD EC Lower bound = $d + 3 + 4 + 5 + 6$(BF) + 3(EF) $= 21 + d$	B1 M1 A1	1.1b 1.1b 2.2a
		(3)	
(e)	Lower bound and upper bound are equal so optimal time is $21 + d$ $21 + d \leq 26$ since upper bound cannot be less than optimal value/lower bound So $3 < d \leq 5$	M1 M1 A1	2.1 2.4 2.2b
		(3)	
		Total: 10 marks	

Notes

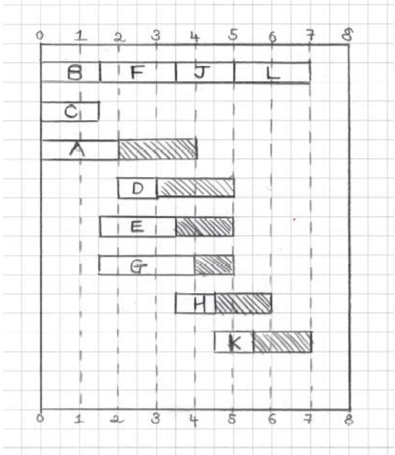
a1B1	CAO
b1B1	CAO
c1B1	Two correct NN routes
c2B1	Two correct corresponding upper bounds for total walking time
d1B1	A correct residual minimum spanning tree found including AD
d1M1	Attempt to find lower bound using: weight of tree + two arcs of least weight from F
d1A1	A MST found and BF and EF or DF and EF added to obtain correct lower bound
e1M1	Reasoning that since lower bound = upper bound, $21 + d$ must be optimal time
e2M1	Deduces that ‘$21 + d$’ $\leq$ ‘26’ with reasoning
e1A1	CAO

Question	Scheme	Marks	AOs
4. (a)	Odd nodes: A, G, J, K A(H)G + J(CE)K = 113 + 125 = 238 A(H)J + G(FE)K = 145 + 92 = 237 A(HGFE)K + G(F)J = 205 + 114 = 319	M1 A1 A1	3.1b 1.1b 1.1b
	Shortest route = 1459 + 237 = 1696 (m) Repeated arcs: AH HJ GF FE EK	dM1 A1	1.1b 2.2a
		(5)	
(b)	Need to repeat shortest pairing not including K so repeat AH & HG New route length = 1459 + 113 = 1572 Saving = 1696 – 1572 = 124 (m)	M1 dM1 A1	2.4 2.1 2.2a
		(3)	
			Total: 8 marks

Notes

a1M1	Three distinct pairings of the correct four odd nodes
a1A1	Two correct pairings and totals
a2A1	Three correct pairing and totals
a2dM1	1457 + shortest pairing
a3A1	CAO
b1M1	Reasoning to include the need to repeat the shortest pairing not including K and AG identified.
b2dM1	1457 + shortest pairing not including K
b1A1	CAO

<table>
<tr><th>Question</th><th>Scheme</th><th>Marks</th><th>AOs</th></tr>
<tr><td>5. (a)</td><td>The constraints contain a mixture of $\leq$ and $\geq$ inequalities</td><td>B1</td><td>3.5b</td></tr>
<tr><td></td><td></td><td>(1)</td><td></td></tr>
<tr><td>(b)</td><td>$3x - 2y + s_1 = 100$
$x + 3y - s_2 + a_1 = 60$
$(s_1, s_2, a_1 \geq 0)$</td><td>B1
B1</td><td>1.1b
2.5</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td>(c)</td><td>$P = 2x - y - Ma_1$ (M arbitrarily large)
So $P = 2x - y - M(60 - x - 3y + s_2)$
So $P - (2 + M)x - (3M - 1)y + Ms_2 = -60M$
<table>
<tr><th>b.v.</th><th>x</th><th>y</th><th>s_1</th><th>s_2</th><th>a_1</th><th>Value</th><th>Row Ops</th></tr>
<tr><td>s_1</td><td>3</td><td>–2</td><td>1</td><td>0</td><td>0</td><td>100</td><td></td></tr>
<tr><td>a_1</td><td>1</td><td>3</td><td>0</td><td>–1</td><td>1</td><td>60</td><td></td></tr>
<tr><td>P</td><td>$-(2 + M)$</td><td>$-(3M - 1)$</td><td>0</td><td>M</td><td>0</td><td>$-60M$</td><td></td></tr>
</table></td><td>M1
A1
M1
A1</td><td>2.1
1.1b
3.3
2.2a</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td>(d)(i)</td><td><table>
<tr><th>b.v.</th><th>x</th><th>y</th><th>s_1</th><th>s_2</th><th>a_1</th><th>Value</th><th>Row Ops</th></tr>
<tr><td>s_1</td><td>$\frac{11}{3}$</td><td>0</td><td>1</td><td>$-\frac{2}{3}$</td><td>$\frac{2}{3}$</td><td>140</td><td>R_1+2R_2</td></tr>
<tr><td>y</td><td>$\frac{1}{3}$</td><td>1</td><td>0</td><td>$-\frac{1}{3}$</td><td>$\frac{1}{3}$</td><td>20</td><td>$R_2 \div 3$</td></tr>
<tr><td>P</td><td>$-\frac{7}{3}$</td><td>0</td><td>0</td><td>$\frac{1}{3}$</td><td>$M - \frac{1}{3}$</td><td>–20</td><td>$R_3 + (3M - 1)R_2$</td></tr>
</table></td><td>M1
A1
B1</td><td>1.1b
1.1b
2.4</td></tr>
<tr><td>(ii)</td><td>Not optimal because there are negative values in the P row.</td><td>A1</td><td>2.2a</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td colspan="4">Total: 11 marks</td></tr>
<tr><th colspan="4">Notes</th></tr>
<tr><td>a1B1</td><td colspan="3">CAO</td></tr>
<tr><td>b1B1</td><td colspan="3">At least one correct constraint</td></tr>
<tr><td>b1B1</td><td colspan="3">Both constraints correct</td></tr>
<tr><td>c1M1</td><td colspan="3">Attempt to modify objective function using M</td></tr>
<tr><td>c1A1</td><td colspan="3">Elimination of artificial variable to correctly rewrite objective function in terms of x, y, and the slack and surplus variables.</td></tr>
<tr><td>c2M1</td><td colspan="3">Profit row correctly filled in</td></tr>
<tr><td>c2A1</td><td colspan="3">CSO for table.</td></tr>
<tr><td>d1M1</td><td colspan="3">Correct pivot located, attempt to divide row. If negative value used then no marks</td></tr>
<tr><td>d1A1</td><td colspan="3">CAO (ignoring row operations)</td></tr>
<tr><td>d1B1</td><td colspan="3">The correct row operations explained either in terms of the old or new pivot rows</td></tr>
<tr><td>d2A1</td><td colspan="3">Correct conclusion.</td></tr>
</table>

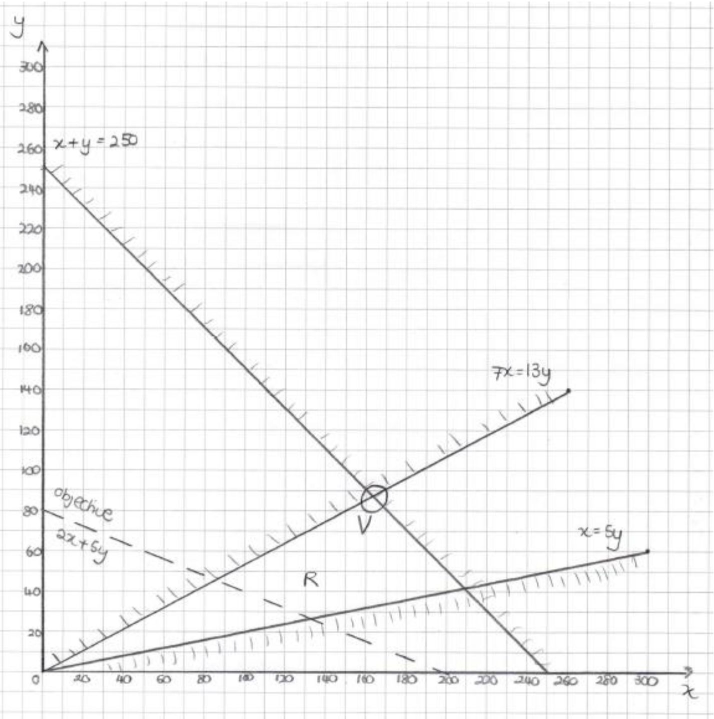
Question	Scheme	Marks	AOs
6. (a)	$t = 1.5$ $u = 4.5$ $v = 3.5$ min time = 7 (hours)	B1 B1 B1	1.1b 1.1b 1.1b
		(3)	
(b)	e.g. Activities which satisfy: Late event time at end point – early event time at start point – activity duration = 0 Critical paths: BFJL and CFJL	B1 B1	1.2 1.1b
		(2)	
(c)		M1 A1 A1	2.1 1.1b 1.1b
		(3)	
(d)	e.g. At time = 3 A, B, C, D can have been completed leaving E, F, G, H, J, K, L For 3 < time < 3.5 E, F, G must be taking place so 3 volunteers required For 3.5 < time < 4 G and J must take place (and H can be delayed) so 2 volunteers required. For 4 < time < 5 J must take place and H can take place (and K can be delayed) so 2 volunteers required. For 5 < time < 6 L must take place and K can take place so 2 volunteers required. So only two volunteers are required after time = 3.5 which is 2.30pm.	M1 A1 A1	3.1b 2.4 2.2a
		(3)	
		Total: 11 marks	

Notes

a1B1	Any two of *t*, *u* and *v* correct
a2B1	All of *t*, *u* and *v* correct
a3B1	CAO
b1B1	CAO
b2B1	Both critical paths stated correctly
c1M1	At least 8 activities placed with at least 3 floats. Scheduling diagram scores M0. Clear distinction must be shown between the notation used for an activity and its float.
c1A1	Critical activities correct and three non-critical activities correct
c2A1	CSO for Gantt chart

d1M1	**Either** a consideration of all times when more than 2 volunteers are required **or** consideration of all times when only two volunteers are required
d1A1	Must give an explanation that refers to all times and activities for when more than 2 volunteers are needed **and** all times and activities for when only 2 volunteers are required.
d2A1	2.30pm stated

Question	Scheme	Marks	AOs
7. (i)	Maximise $6g + 10p$	B1	3.3
	Subject to:		
	$g + p \leq 250$	B1	3.3
	$7p \leq 3g$	M1A1	3.3,1.1b
	$6p \geq g$	B1	3.3
	$(g, p \geq 0)$		
		(5)	
(ii)(a)		B1 B1 B1 B1	1.1b 1.1b 1.1b 3.1a



Question	Scheme	Marks	AOs
	Optimal where $7x = 13y$ and $x + y = 250$ intersect	dM1	3.4
	$x = 162.5$, $y = 87.5$	A1	1.1b
	x and y must be integers.	M1 M1	3.5a 1.1b

x	y	$x + y \leq 250$	$7x \geq 13y$	P
162	87	Y	Y	759
162	88	Y	N	
163	87	Y	Y	761
163	88	N		

Question	Scheme	Marks	AOs
	Ishi should sell 163 Type A tickets and 87 Type B tickets	A1	3.2a
(b)	So maximum amount of money = £761	A1	2.2a
		(10)	
		Total: 15 marks	

Notes	
a1B1	CAO objective function + maximise
a2B1	CAO: $g + p \leq 250$
a1M1	$7p \square 3g$ where $\square$ is any inequality or equals, or $3p \leq 7g$
a1A1	CAO: $7p \leq 3g$
a3B1	CAO: $6p \geq g$

b1B1	$x + y = 250$ drawn correctly – must pass within one small square of (0, 250) and (250, 0)
b2B1	$7x = 13y$ drawn correctly – must pass within one small square of (0,0) and (260, 140)
b3B1	$x = 5y$ drawn correctly – must pass within one small square of (0, 0) and (300, 60)
b4B1	Selects a suitable strategy to find the optimal vertex. Must see evidence of either the correct or reciprocal objective line, OR point testing of (162.5, 87.5) and $(\frac{625}{3},\frac{125}{3})$ in their objective function for this mark.
b1dM1	Simultaneous equations used to find their V. Correct exact coordinates for V with no working can score this mark. This mark is dependent on all three constraint lines drawn correctly.
b1A1	Correct exact coordinates of V.
b2M1	Identifies need to consider integer values.
b3M1	An integer point around (162.5, 87.5) tested in **both** $x + y \leq 250$ **and** $7x \geq 13y$
b2A1	CAO
b3A1	CAO