AQA

A-level
Mathematics

MD02 – Decision 2
Mark scheme

6360
June 2016

Version: 1.0 Final Mark Scheme

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from aqa.org.uk

Key to mark scheme abbreviations

M	mark is for method
m or dM	mark is dependent on one or more M marks and is for method
A	mark is dependent on M or m marks and is for accuracy
B	mark is independent of M or m marks and is for method and accuracy
E	mark is for explanation
√or ft or F	follow through from previous incorrect result
CAO	correct answer only
CSO	correct solution only
AWFW	anything which falls within
AWRT	anything which rounds to
ACF	any correct form
AG	answer given
SC	special case
OE	or equivalent
A2,1	2 or 1 (or 0) accuracy marks
–*x* EE	deduct *x* marks for each error
NMS	no method shown
PI	possibly implied
SCA	substantially correct approach
c	candidate
sf	significant figure(s)
dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

<table>
<tr><th>Q1</th><th>Solution</th><th>Mark</th><th>Total</th><th>Comment</th></tr>
<tr><td>a</td><td>
<table>
<tr><th>Activity</th><th>Early</th><th>Late</th></tr>
<tr><td>A</td><td>0</td><td>9</td></tr>
<tr><td>B</td><td>0</td><td>9</td></tr>
<tr><td>C</td><td>0</td><td>22</td></tr>
<tr><td>D</td><td>8</td><td>15</td></tr>
<tr><td>E</td><td>14</td><td>29</td></tr>
<tr><td>F</td><td>22</td><td>29</td></tr>
<tr><td>G</td><td>22</td><td>29</td></tr>
<tr><td>H</td><td>28</td><td>42</td></tr>
<tr><td>I</td><td>29</td><td>41</td></tr>
<tr><td>J</td><td>41</td><td>50</td></tr>
<tr><td>K</td><td>41</td><td>50</td></tr>
<tr><td>L</td><td>50</td><td>58</td></tr>
</table>
</td><td>M1

A1

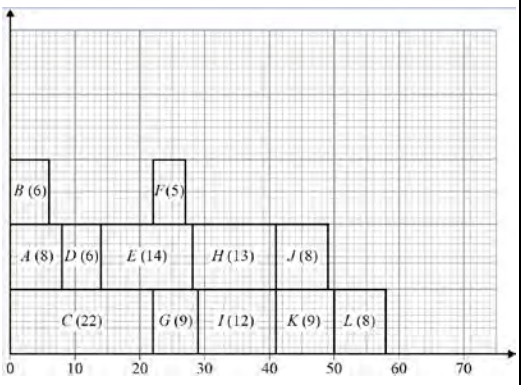
M1

A1</td><td>

4</td><td>Early times correct at E, F, H and I

All correct

Late times correct at I, H, F and E
ft their answer to part (a)

All correct</td></tr>
<tr><td>b(i)</td><td>CGIKL</td><td>B1</td><td>1</td><td></td></tr>
<tr><td>(ii)</td><td>2</td><td>B1</td><td>1</td><td></td></tr>
<tr><td>(c)</td><td> 
</td><td>M1

A1

A1</td><td>

3</td><td>SCA, resource histogram, at least 10 labelled activities shown, condone floats.

Two ‘complete’ horizontal rows, but no ‘vertical gaps’, showing correct progression, correct start times, (condone floats).

All correct. (no floats) oe</td></tr>
<tr><td>(d)(i)</td><td>A, B, D must be allocated to 1 worker
Leading to an answer $63 \le x < (58+11)$
63</td><td>M1

A1</td><td>

2</td><td>PI by part (ii)</td></tr>
<tr><td>(ii)</td><td>(A, B, D, E), (H, J), L
(C, F, G), (I, K), (L)</td><td>B1</td><td>

1</td><td>{A, B}, D, E together
and C,{ F, G} together, then
H, J together and I, K together</td></tr>
<tr><td></td><td>Total</td><td></td><td>12</td><td></td></tr>
</table>

Notes:

(a) The 2nd **A** mark is correct answer only (no ft)

(c) For first **A** mark**:** No ‘vertical gaps’, eg *E* cannot be above *F*, unless *E* is split into 2 sections
Floats seen ‘overlapping’ into next activity can still score first **A1** but not second **A1**
Gantt diagram score **M0**

(d)(i) NMS 63 scores 2/2,
If **M0** scored the B1 mark in (ii) is still available

(d)(ii) answer may be seen in part (i)
{*A, B*} may be in either order, same for {*F, G*}

Q2	Solution	Mark	Total	Comment
a	x 2 3 3 1 ***or*** x 0 5 4 1 1 0 1 0 0 1 0 5 3 2 9 x 8 7 6 1 x 4 2 0 0 1 0 0 0 0 1 4 3 2 4 x 4 4 5 0 x 4 3 3 **(A)** **(B) or (C)**	**M1**		Using column or row minima, The 'x' could be a number ≥ 20, or a 'dash', or omitted At least 4 rows or columns correct (lines, or lack of, are not needed here)
	x 1 2 2 0 x 0 1 2 1 1 0 1 0 0 1 0 1 1 2 3 x 2 1 0 1 x 0 0 0 0 1 0 0 0 0 1 0 1 2 0 x 0 0 1 0 x 0 1 3 **(A)** **(B)**	**m1** **A1** **B1**		Using row or column minima At least 4 columns or rows correct All numbers correct Correct use of 4 lines
	x 0 1 2 1 1 0 1 1 2 1 x 0 0 0 0 1 0 1 2 0 x 0 1 3 **(C)**			
	x 0 1 1 0 x 0 1 1 0 1 0 1 0 1 1 0 1 0 1 2 x 1 0 0 2 x 1 0 0 0 1 0 0 1 0 1 0 0 1 0 x 0 0 2 0 x 0 0 2 **(A)** **(B)**	**m1**		Reduce all uncovered elements by 1, Leave all one line elements Add 1 to all double line elements Condone 1 (new) slip, but must have score **M1m1**
	or x 0 0 1 0 0 0 0 0 1 1 x 0 0 0 0 2 0 1 2 0 x 0 1 3 **(C)**	**A1**		All numbers correct
	Correct use of 5 lines AND optimal	**B1**		Condone 'complete'
	A4, B2, C5, D3, E1 or A4, B1, C5, D2, E3 or A5, B2, C4, D3, E1 or A5, B1, C4, D2, E3	**B1** **B1**	**9**	Three correct allocations All 4 correct and no extras
b	[£] 61	**B1**	**1**	Condone omission of units
	Total		**10**	

Q3	Solution	Mark	Total	Comment
a	P x y z r s t 1 -2 3 -4 0 0 0 0 0 1 2 1 1 0 0 20 0 1 -1 3 0 1 0 24 0 3 -2 2 0 0 1 30	**M1** **A1** **2**		3 rows correct (must include slack variables) All correct
b(i)	20/1, 24/3, 30/2 ALL seen '3' in z-col identified	**E1** **B1** **2**		Correct **value** may be highlighted in table
(ii)	P x y z r s t 1 -2/3 5/3 0 0 4/3 0 32 0 2/3 7/3 0 1 -1/3 0 12 0 1/3 -1/3 1 0 1/3 0 8 0 7/3 -4/3 0 0 -2/3 1 14	**M1** **A1** **A1** **3**		P x y z r s t 3 -2 5 0 0 4 0 96 0 2 7 0 3 -1 0 36 0 1 -1 3 0 1 0 24 0 7 -4 0 0 -2 3 42 SCA - Row reduction, 1 row correct (other than (shaded) pivot row) Any 3 rows correct All correct
(iii)	P x y z r s t 1 0 9/7 0 0 8/7 2/7 36 0 0 19/7 0 1 -1/7 -2/7 8 0 0 -1/7 1 0 3/7 -1/7 6 0 1 -4/7 0 0 -2/7 3/7 6	**B1F** **M1** **A1** **3**		P x y z r s t 21 0 27 0 0 24 6 756 0 0 57 0 21 -3 -6 168 0 0 -3 21 0 9 -3 126 0 7 -4 0 0 -2 3 42 18, [24], 6 seen and correct pivot x-col Row reduction, 1 row correct (other than (shaded) pivot row) All correct
c	**In part (c), FT ONLY IF all non-negative in profit row.** **All answers must be exact. (isw)** Max $P = 36$ $x = 6,\ y = 0,\ z = 6$ $r = 8,\ s = 0,\ t = 0$	**B1F** **B1F** **B1F** **3**		Max/optimal oe stated in part (c) or end of part (b) FT their values, must be non-negative must be non-negative
	Total		**13**	

Notes:

Working for one part may be seen by the previous table

(b)(i) 20, 8, 15 may be seen without working

Condone intersection of correct row with correct column

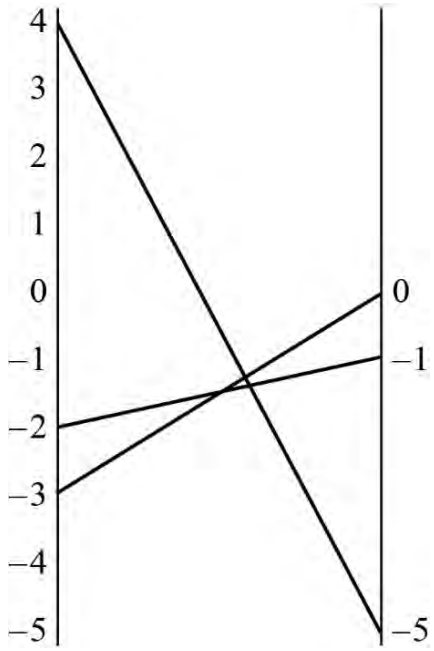
(iii) 18, 24, 6 may be unsimplified ratios eg $12 \div (2/3),\ 8 \div (1/3),\ 14 \div (7/3)$

Condone omission of 24, or their pivot 'row' from part (ii)

Condone any row operations that produce an equivalent answer eg multiple of -1

(c) Optimal may appear in a general statement eg 'an optimal solution has been found', and then $P =$

Their slack variables may be different letters, answers must correspond respectively.

Q4	Solution	Mark	Total	Comment
a	For **each pair of strategies,** whatever one player wins, the other person loses.	**E1**	**1**	Must see this statement oe and Row gain + Col gain = 0 oe
b	Row min -5, -5, -3 [Max value -3] Col max -1, 4, 0 [Min value -1] Monica [plays] ***C*** **and** Vladimir [plays] ***D***	**M1** **A1**	**2**	All 6 values correct Must be in context
c	Row *C* dominates Row *B* [Monica plays *A* with probability *p* plays *C* with probability $1-p$] [Vladimir plays]	**E1**		Row *B* is dominated by row *C*
	D, Monica wins $-p-2(1-p)=p-2$ *E*, Monica wins $-5p+4(1-p)=4-9p$ *F*, Monica wins $-3(1-p)=3p-3$	**M1** **A1**		One expression correct (unsimplified) All 3 correct (unsimplified)
		**M1** **A1**		Must have exactly three straight lines All correct (eg 4 to -5, -2 to -1, -3 to 0) With numbers on vertical axes shown
	Max point at $4-9p=p-2$ $p=\frac{3}{5}$	**m1**		Correct equation **PI** by correct value for *p*
	Monica plays A [with probability] $\frac{3}{5}$ oe Monica plays C [with probability] $\frac{2}{5}$ oe	**A1**		Both statements needed (condone omission of 'play B [with probability] zero')
	Value of game = $\frac{3}{5}-2$ or $4-9\times\frac{3}{5}$ $=-1.4$ or $-\frac{7}{5}$ **AG**	**A1**	**8**	Must see correct substitution of $p = 0.6$ Must include statement and no errors seen (condone $V =$)

Q4	Solution	Mark	Total	Comment
d	[Monica plays] [A, Vladimir loses] $-p-5q$ [C, Vladimir loses] $-2p+4q-3(1-p-q)$	**M1**		Either expression correct
	$-p-5q=-1.4$ $-2p+4q-3(1-p-q)=-1.4$	**A1**		Both equations correct (or simplified versions eg $p + 7q = 1.6$)
	$q=0.1$ $p=0.9,$ $(1-p-q=0)$	**A1**		Either p or q correct
	Vladimir plays *D* [with probability] 0.9 plays *E* [with probability] 0.1 plays *F* [with probability] 0 (or, never plays *F*)	**E1**		Must have all 3 probabilities
	Or,			
	[A, Vladimir loses] $-p-5(1-p)$ [C, Vladimir loses] $-2p+4(1-p)$	**(M1)**		Either expression correct, **but must have discounted F, here, or on final line**
	Equating to -1.4	**(A1)**		Or, equating to each other
	$p=0.9$	**(A1)**		
	Vladimir plays *D* [with probability] 0.9 plays *E* [with probability] 0.1 **plays *F* [with probability] 0** (or, **never plays *F*)**	**(E1)**		Must have all 3 probabilities
			4	
	Total		**15**	

Notes:

(b) condone required values seen in the table in the question space

(d) candidate might not use the letters *p*, *q* but use other letters eg *m*, *n*

Candidates might use value of game as 1.4 and then expressions in *p*, *q* would have signs reversed, but DO NOT allow signs reversed if -1.4 is used for first **M** mark.

Q5	Solution	Mark	Total	Comment
a	Insert table from below			
	May:	**B1**		Exactly 12 rows seen at this stage
	8 of their calculations/profits correct	**M1**		
		A1		All profits correct
		B1		Their 6 maxima values identified (**PI** by further work)
	April:	**B1**		Exactly 12 rows seen at this stage
	9 or more calculations/profits correct	**M1**		
		A1		All profits correct
	March:			
	3 or more calculations/profits correct	**M1**		
		A1		All profits correct
	Order *DBCA*	**B1**		
			10	
b	£28100	**B1**		Must include '£' Allow equivalent in words
			1	
	Total		**11**	

Stage (Month)	State (houses renovated)	Action	Calculation	Profit (£ x00's)
June	*A, B, C*	*D*		88
	A, B, D	*C*		83
	A, C, D	*B*		70
	B, C, D	*A*		66
May	*A, B*	*C*	75 + 88	163
		D	81 + 83	164 x
	A, C	*B*	59 + 88	147
		D	80 + 70	150 x
	A, D	*B*	62 + 83	145 x
		C	74 + 70	144
	B, C	*A*	56 + 88	144
		D	85 +66	151 x
	B, D	*A*	59 + 83	142
		C	77 + 66	143 x
	C, D	*A*	57 + 70	127 x
		B	60 + 66	126
April	*A*	*B*	60 + 164	224 x
		C	71 + 150	221
		D	75 + 145	220
	B	*A*	50 + 164	214
		C	70 + 151	221 x
		D	77 + 143	220
	C	*A*	47 + 150	197
		B	56 + 151	207 x
		D	79 + 127	206
	D	*A*	52 + 145	197
		B	68 + 143	211 x
		C	68 + 127	195
March		*A*	40 + 224	264
		B	55 + 221	276
		C	60 + 207	267
		D	70 + 211	281 x

<table>
<tr><th>Q6</th><th>Solution</th><th>Mark</th><th>Total</th><th>Comment</th></tr>
<tr><td>ai</td><td>45</td><td>B1</td><td>1</td><td></td></tr>
<tr><td>ii</td><td>≤ 45 Oe in words</td><td>B1F</td><td>1</td><td></td></tr>
<tr><td>b</td><td>$BD = 4$
$BE = 4$
$CD = 6$</td><td>B1
B1
B1</td><td>3</td><td></td></tr>
<tr><td>ci</td><td>
<table>
<tr><th>Edge</th><th>Forward</th><th>Back</th></tr>
<tr><td>AB</td><td>1</td><td>6</td></tr>
<tr><td>AC</td><td>1</td><td>8</td></tr>
<tr><td>AD</td><td>2</td><td>3</td></tr>
<tr><td>BE</td><td>3</td><td>2</td></tr>
<tr><td>BH</td><td>3</td><td>0</td></tr>
<tr><td>BD</td><td>4</td><td>2</td></tr>
<tr><td>CD</td><td>0</td><td>3</td></tr>
<tr><td>CF</td><td>2</td><td>1</td></tr>
<tr><td>DH</td><td>0</td><td>1</td></tr>
<tr><td>DF</td><td>0</td><td>1</td></tr>
<tr><td>EG</td><td>3</td><td>0</td></tr>
<tr><td>EH</td><td>3</td><td>0</td></tr>
<tr><td>FH</td><td>3</td><td>3</td></tr>
<tr><td>GH</td><td>2</td><td>0</td></tr>
</table>
</td><td>M1

A1

A1</td><td>3</td><td>Correct at least one of AB, AC, AD, DH including directions, shown on diagram

All correct at AB, AC, AD, DH including directions, shown on diagram

All correct</td></tr>
<tr><td>ii</td><td>Modifying one feasible flow correctly on diagram, must have scored M1 in part (i)

eg
<table>
<tr><th>Flow</th><th>Value</th></tr>
<tr><td>ABEGH</td><td>1</td></tr>
<tr><td>ADBH</td><td>2</td></tr>
<tr><td>ACFH</td><td>1</td></tr>
</table>
</td><td>B1

M1
A1

A1</td><td>4</td><td>Augmenting both increases and decreases on one flow

One correct flow in table
Second flow correct in table

All correct</td></tr>
<tr><td>iii</td><td>[Max flow =] 32
Diagram must have
$AB = 12$, $AC = 11$, $AD = 9$,
$GH + EH + BH + DH + FH = 32$
Different possibilities for other edges</td><td>B1

B1</td><td>2</td><td>

All correct</td></tr>
<tr><td></td><td>Total</td><td></td><td>14</td><td></td></tr>
</table>

Notes:

ci Different notation may be seen eg on *AB* 1, 6 (reverse from standard notation), then this 'order' must be consistent on **all** edges

cii Flow *AD…H* might be seen in 2 flows

Flow	Value
AB….H	1
AD….H	2
AC.…H	1

x	2	3	3	1	***or***	x	0	5	4	1
1	0	1	0	0		1	0	5	3	2
9	x	8	7	6		1	x	4	2	0
0	1	0	0	0		0	1	4	3	2
4	x	4	4	5		0	x	4	3	3

x	1	2	2	0	***or***	x	0	1	2	1	***or***	x	0	1	2	1
1	0	1	0	0		1	0	1	1	2		1	0	1	1	2
3	x	2	1	0		1	x	0	0	0		1	x	0	0	0
0	1	0	0	0		0	1	0	1	2		0	1	0	1	2
0	x	0	0	1		0	x	0	1	3		0	x	0	1	3

x	0	1	1	0	***or***	x	0	1	1	0	***or***	x	0	0	1	0
1	0	1	0	1		1	0	1	0	1		0	0	0	0	1
2	x	1	0	0		2	x	1	0	0		1	x	0	0	0
0	1	0	0	1		0	1	0	0	1		0	2	0	1	2
0	x	0	0	2		0	x	0	0	2		0	x	0	1	3