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# A-Level Mathematics

MD02 Decision 2  
Final Mark scheme

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6360  
June 2017

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Version/Stage: v1.0

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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](http://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.**

Q1	Solution	Mark	Total	Comment
<b>a</b>	Only ‘non-negatives’ in profit row      oe	<b>E1</b>	<b>1</b>	
<b>b</b>	$P = 20$ $x = 6, \ y = 0, \ z = 1$ $r = 0, \ s = 0.25, \ t = 0$	<b>B1</b> <b>B1</b> <b>B1</b>	<b>3</b>	
	<b>Total</b>		<b>4</b>	
<b>Notes:</b> Do not accept ‘positive’, but do accept ‘all positive or zero’				

Q2	Solution	Mark	Total	Comment
	<p>Erica:  Row min <math>(-2, -4, -2, -3)</math>  Max(rowmin) = <math>-2</math></p> <p>Playsafe Erica = A, C</p> <p>Viggo:  Col max <math>(4, 0, 3, 4)</math>  Min(colmax) = <math>0</math></p> <p>Playsafe Viggo = X</p> <p>Max(rowmin) <math>[-2] \neq [0 =]</math> Min(colmax)  There is no stable soln</p>	<p><b>B1*</b></p> <p><b>B1</b></p> <p><b>(B1*)</b></p> <p><b>B1</b></p> <p><b>E1</b></p>		<p>Earned here, all correct 4 values seen and at least one <math>-2</math> highlighted or stated.</p> <p>Both needed, and no others</p> <p>Or here, all correct 4 values seen and 0 highlighted or stated</p> <p>And no others</p> <p>Must have statement and conclusion  Must see 'Max(rowmin) = <math>-2</math>' and 'Min(colmax) = <math>0</math>', either here or earlier in their solution</p>
	<b>Total</b>		<b>4</b>	

**Notes:**

If a candidate has used (complete) dominance:

$A > D$

then  $X > Z$

then  $A > B$

then  $Y > W$

Erica: Max(rowmin)  $(-2, -2) = -2$  (**B1\*** here)

play-safe A, C (**B1**)

Viggo: Min (colmax)  $(0, 3) = 0$  (**B1\*** or here)

play-safe X (**B1**)

Conclusion as above (**E1**)

If a candidate has started dominance and then stopped after  $A > D$  etc, then their numbers will reflect the size of their reduced matrix ie every use of dominance reduces their rowmin or colmax by 1 value

The **E1** mark is not FT

Q 3	Solution	Mark	Total	Comment																																																																																																				
(a)	<p>Reduce rows:</p> <table border="1"> <tr><td>7</td><td>17</td><td>17</td><td>7</td><td>0</td></tr> <tr><td>10</td><td><math>x - 20</math></td><td>0</td><td>10</td><td>5</td></tr> <tr><td>4</td><td>9</td><td>0</td><td>7</td><td>9</td></tr> <tr><td>7</td><td>5</td><td>10</td><td>10</td><td>0</td></tr> <tr><td>2</td><td>0</td><td>1</td><td>2</td><td>4</td></tr> </table> <p>Reduce cols</p> <table border="1"> <tr><td>5</td><td>17</td><td>17</td><td>5</td><td>0</td></tr> <tr><td>8</td><td><math>x - 20</math></td><td>0</td><td>8</td><td>5</td></tr> <tr><td>2</td><td>9</td><td>0</td><td>5</td><td>9</td></tr> <tr><td>5</td><td>5</td><td>10</td><td>8</td><td>0</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>0</td><td>4</td></tr> </table> <p>Covered with exactly 3 lines, reduce by 2</p> <table border="1"> <tr><td>3</td><td>15</td><td>17</td><td>3</td><td>0</td></tr> <tr><td>6</td><td><math>x - 22</math></td><td>0</td><td>6</td><td>5</td></tr> <tr><td>0</td><td>7</td><td>0</td><td>3</td><td>9</td></tr> <tr><td>3</td><td>3</td><td>10</td><td>6</td><td>0</td></tr> <tr><td>0</td><td>0</td><td>3</td><td>0</td><td>6</td></tr> </table> <p>Covered with exactly 4 lines, reduce by 3 (other lines possible)</p> <table border="1"> <tr><td>3</td><td>12</td><td>17</td><td>0</td><td>0</td></tr> <tr><td>6</td><td><math>x - 25</math></td><td>0</td><td>3</td><td>5</td></tr> <tr><td>0</td><td>4</td><td>0</td><td>0</td><td>9</td></tr> <tr><td>3</td><td>0</td><td>10</td><td>3</td><td>0</td></tr> <tr><td>3</td><td>0</td><td>6</td><td>0</td><td>9</td></tr> </table> <p>Covered by <b>exactly</b> 5 lines, so optimal OE</p> <p>Match AX, BY, CW, DZ, EV AX, BZ, CW, DV, EY</p> <p>Time 75 (mins)</p>	7	17	17	7	0	10	$x - 20$	0	10	5	4	9	0	7	9	7	5	10	10	0	2	0	1	2	4	5	17	17	5	0	8	$x - 20$	0	8	5	2	9	0	5	9	5	5	10	8	0	0	0	1	0	4	3	15	17	3	0	6	$x - 22$	0	6	5	0	7	0	3	9	3	3	10	6	0	0	0	3	0	6	3	12	17	0	0	6	$x - 25$	0	3	5	0	4	0	0	9	3	0	10	3	0	3	0	6	0	9	<p><b>M1</b></p> <p><b>A1</b></p> <p><b>dM1</b></p> <p><b>dM1</b></p> <p><b>A1</b></p> <p><b>E1</b></p> <p><b>B1</b></p> <p><b>B1</b></p> <p><b>B1</b></p>	<p>9</p>	<p>All correct, condone up to 2 slips</p> <p>All correct</p> <p>Subtract 2 from all uncovered, add 2 to all 'double' covered, leave single covered unaltered (condone 1 slip)</p> <p>Subtract 3 from all uncovered, add 3 to all 'double' covered, leave single covered unaltered (condone 1 slip)</p> <p>All correct – other correct final tables shown below</p> <p>Must see this line</p> <p>One correct match</p> <p>Second correct match and no others</p>
7	17	17	7	0																																																																																																				
10	$x - 20$	0	10	5																																																																																																				
4	9	0	7	9																																																																																																				
7	5	10	10	0																																																																																																				
2	0	1	2	4																																																																																																				
5	17	17	5	0																																																																																																				
8	$x - 20$	0	8	5																																																																																																				
2	9	0	5	9																																																																																																				
5	5	10	8	0																																																																																																				
0	0	1	0	4																																																																																																				
3	15	17	3	0																																																																																																				
6	$x - 22$	0	6	5																																																																																																				
0	7	0	3	9																																																																																																				
3	3	10	6	0																																																																																																				
0	0	3	0	6																																																																																																				
3	12	17	0	0																																																																																																				
6	$x - 25$	0	3	5																																																																																																				
0	4	0	0	9																																																																																																				
3	0	10	3	0																																																																																																				
3	0	6	0	9																																																																																																				
	<b>Total</b>		<b>9</b>																																																																																																					

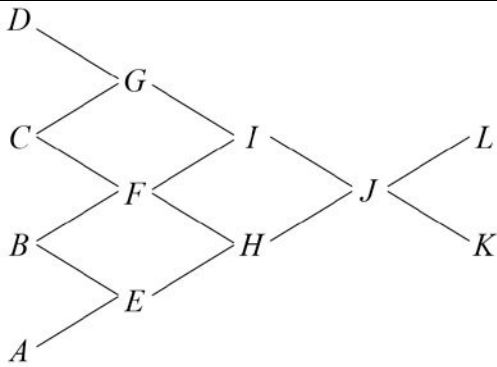
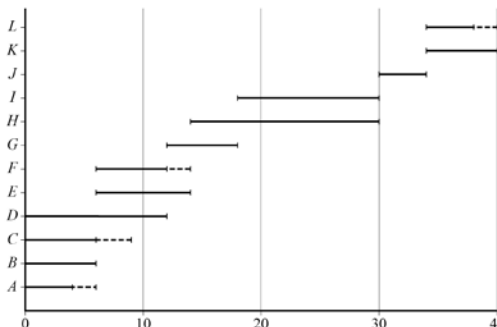
**Notes:**

Other possible correct final tables

'Working' might be in extra stages eg reduce by 1 and then again reduce by 1 – ignore extra steps

0	12	17	0	0
3	$x - 25$	0	3	5
0	7	3	3	12
0	0	10	3	0
0	0	6	0	9

0	12	14	0	0
6	$x - 22$	0	6	8
0	7	0	3	12
0	0	7	3	0
0	0	3	0	9

Q4	Solution	Mark	Total	Comment																																						
(a)		M1  A1	2	Network diagram, 11+ connected activities  All correct (condone ‘extra end’ activity)																																						
(b)(i)	<table border="1"><thead><tr><th>Task</th><th>Early</th><th>Late</th></tr></thead><tbody><tr><td>A</td><td>0</td><td>6</td></tr><tr><td>B</td><td>0</td><td>6</td></tr><tr><td>C</td><td>0</td><td>12 or 14−<i>x</i></td></tr><tr><td>D</td><td>0</td><td>12</td></tr><tr><td>E</td><td>6</td><td>14</td></tr><tr><td>F</td><td>6</td><td>14</td></tr><tr><td>G</td><td>12</td><td>19</td></tr><tr><td>H</td><td>14</td><td>30</td></tr><tr><td>I</td><td>19</td><td>30</td></tr><tr><td>J</td><td>30</td><td>34</td></tr><tr><td>K</td><td>34</td><td>40</td></tr><tr><td>L</td><td>34</td><td>40</td></tr></tbody></table>	Task		Early	Late	A	0	6	B	0	6	C	0	12 or 14− <i>x</i>	D	0	12	E	6	14	F	6	14	G	12	19	H	14	30	I	19	30	J	30	34	K	34	40	L	34	40	M1 A1  M1 A1ft
Task	Early	Late																																								
A	0	6																																								
B	0	6																																								
C	0	12 or 14− <i>x</i>																																								
D	0	12																																								
E	6	14																																								
F	6	14																																								
G	12	19																																								
H	14	30																																								
I	19	30																																								
J	30	34																																								
K	34	40																																								
L	34	40																																								
(ii)	<i>BEHJK</i> <i>DGIJK</i>	B1	5	Both critical paths correct and no extras																																						
(c)(i)	32 + <i>x</i>	M1 A1	3	<i>x</i> + <i>k</i> , where <i>k</i> ≥ 32																																						
(ii)	2	B1																																								
(d)		M1 B1 A1	3	SCA, at least 10 labelled activities Use of floats, at least 2 of <i>A, C, F, L</i> All correct, including labelling and all floats correct																																						
	Total		3 13																																							

**Notes:**

(d) For a correct, but different, Gantt diagram, the M1 can only be scored for 10+ activities labelled AND; a critical path on one row, all other critical activities on a second row (and nothing else), and each non-critical activity on its own row. The A mark is as above.

The floats may be before the activity or after the activity

Q5	Solution								Mark	Total	Comment		
	$P$	$x$	$y$	$z$	$r$	$s$	$t$	$V$	<b>B1</b>		3 rows correct		
	1	-2	3	-5	0	0	0	0					
	0	3	-2	<u>2</u>	1	0	0	44					
	0	4	2	-1	0	1	0	44					
	0	5	1	-4	0	0	1	44					
	Row 2 in $z$ -col as pivot								<b>E1</b>		'2' highlighted		
	2	11	-4	0	5	0	0	220	<b>M1</b>		SCA – row reduction, 2+ rows correct		
	0	3	-2	2	1	0	0	44	<b>A1</b>		All correct		
	0	11	<u>2</u>	0	1	2	0	132	<b>dM1</b>		SCA – row reduction, 3+ rows correct		
	0	11	-3	0	2	0	1	132					
	Row 3 in $y$ -col as pivot											<b>E1</b>	'2' highlighted
	2	33	0	0	7	4	0	484				<b>A1</b>	All correct
	0	14	0	2	2	2	0	176					
	0	11	2	0	1	2	0	132					
	0	55	0	0	7	6	2	660					
	Max $P = 242$ $x = 0, y = 66, z = 88, r = 0, s = 0, t = 330$								<b>B1</b> <b>B1</b>		'Profit row' must only contain non-negatives for the following marks to be available Must include 'max/optimal' All stated		
Total										<b>10</b>			
<b>Notes:</b> In all tables, the rows can be a multiple of the given answer – see below Slack variables may be different to $r, s, t$ (possibly $s, t, u$ , in which case $t = 0$ and $u = 330$ )													



Eg reducing the pivots to 1

$P$	$x$	$y$	$z$	$r$	$s$	$t$	$V$
1	-2	3	-5	0	0	0	0
0	3	-2	2	1	0	0	44
0	4	2	-1	0	1	0	44
0	5	1	-4	0	0	1	44

1	$11/2$	-2	0	$5/2$	0	0	110
0	$3/2$	-1	1	$1/2$	0	0	22
0	$11/2$	1	0	$1/2$	1	0	66
0	11	-3	0	2	0	1	132

1	$33/2$	0	0	$7/2$	2	0	242
0	7	0	1	1	1	0	88
0	$11/2$	1	0	$1/2$	1	0	66
0	$55/2$	0	0	$7/2$	3	1	330

Q6	Solution	Mark	Total	Comment
	(J never plays B as) A dominates B J plays A with prob $p$ , and C with prob $1-p$	<b>E1</b>		
	Nigel plays D, J wins $3p - 1(1 - p) = 4p - 1$	<b>M1</b>		Any expression correct, in either simplified/unsimplified form
	plays E, J wins $p + 2(1 - p) = 2 - p$	<b>A1</b>		All 3 correct, in either simplified/unsimplified form
	plays F, J wins $-2p + 4(1 - p) = 4 - 6p$	<b>M1</b>		
	Graph, at least one vertical axis, with scale labelled, and 3 ruled 'diagonal' lines	<b>M1</b>		
	Ruled line connecting -1 to 3 Ruled line connecting 2 to 1 Ruled line connecting 4 to -2	<b>A1</b>		All 3 lines correct, 2 vertical axes, including scales on both axes
	[Max point at] $4p - 1 = 4 - 6p$ [ $p = 0.5$ ]	<b>M1</b>		
	Jeremy plays A with prob 0.5 Jeremy plays B with prob 0 Jeremy plays C with prob 0.5	<b>A1</b>		Must have all 3 statements
	(Value of game for J = 1) Value of game for Nigel = -1	<b>B1</b>		Must be clear that their answer is value of game for Nigel
	<b>Total</b>		<b>8</b>	
<b>Notes:</b> Candidate might have said 'never plays B' at start for final <b>A1</b>				

Q7	Solution					Mark	Total	Comment
	Stage	State	From	Calculation	Value	<div>M1 A1</div> <div>B1</div> <div>dM1</div> <div>A1</div> <div>B1</div> <div>A1</div> <div>A1</div> <div>B1 B1</div>		<div>their max at <i>H</i> indicated All 4 values correct</div> <div>8 values their max values at <i>D</i> and <i>E</i> indicated</div> <div>All 8 values correct</div> <div>6 values</div> <div>All 6 values correct including two ‘58’ and ‘60’ indicated</div> <div>Both values correct, including 80 indicated Or stated Max = £80</div> <div>A correct route 2<sup>nd</sup> correct route and no others</div>
	1	<i>J</i>	<i>T</i>		20			
		<i>K</i>	<i>T</i>		18			
	2	<i>G</i>	<i>J</i>	(30 + 20)	50 (*)			
		<i>H</i>	<i>J</i>	(22 + 20)	42			
		<i>H</i>	<i>K</i>	(25 + 18)	43 *			
		<i>I</i>	<i>K</i>	(26 + 18)	44 (*)			
	3	<i>C</i>	<i>G</i>	(50 – 8)	42 (*)			
		<i>D</i>	<i>G</i>	(50 – 12)	38			
		<i>D</i>	<i>H</i>	(43 – 4)	39			
		<i>D</i>	<i>I</i>	(44 – 4)	40 *			
		<i>E</i>	<i>G</i>	(50 – 10)	40			
		<i>E</i>	<i>H</i>	(43 – 4)	39			
		<i>E</i>	<i>I</i>	(44 – 3)	41 *			
		<i>F</i>	<i>I</i>	(44 – 7)	37 (*)			
	4	<i>A</i>	<i>C</i>	(42 + 17)	59			
		<i>A</i>	<i>D</i>	(40 + 18)	58			
		<i>A</i>	<i>E</i>	(41 + 19)	60 *			
		<i>B</i>	<i>D</i>	(40 + 18)	58 *			
		<i>B</i>	<i>E</i>	(41 + 17)	58 *			
		<i>B</i>	<i>F</i>	(37 + 20)	57			
5	<i>S</i>	<i>A</i>	(60 + 19)	79				
	<i>S</i>	<i>B</i>	(58 + 22)	80 *				
Routes SBDIKT SBEIKT								
Total							10	
Notes: For dM1 a candidate may have more than 4 ‘max’ ie duplicate values								

Q8	Solution	Mark	Total	Comment
(a)(i)	37	B1	2	Need 'min' and 4, 2, 3
(ii)	43	B1		
(b)(i)	Min flow leaving B is $4 + 2 + 3$	E1		
(ii)	25	B1		
(c)				
	<i>SB, BA, BD, BC, DF, EF, GF, FT</i> correct	B1		ie correct at <i>B</i> and <i>F</i>
	<i>SC, SA, AD, AE, CD, CG, ET, GT</i> correct	B1		
				2
	Total		6	
Notes:				
(c) condone omission of 'arrows'				

Q9	Solution	Mark	Total	Comment												
(a)	Adding edges $SP, SQ, XT, YT, ZT$	B1		$S$ and $T$ must be clearly labelled If other label(s) used, only penalise here												
			1													
(b)		M1 A1 A1	3	Correct values of potential increases and decreases at one of $PA, PB, QB, QC$  Correct increases and decreases, including directions at both $AX$ and $DX$ or both $EZ$ and $CZ$  All correct												
(c)	<table><thead><tr><th>Route</th><th>Flow</th></tr></thead><tbody><tr><td><math>SPAXT</math></td><td>1</td></tr><tr><td><math>SPADYT</math></td><td>1</td></tr><tr><td><math>SPBEYT</math></td><td>1</td></tr><tr><td><math>SQCZT</math></td><td>3</td></tr><tr><td>Total</td><td>6</td></tr></tbody></table> <p>All augmentations correctly showing an increase of 6 on diagram</p>	Route		Flow	$SPAXT$	1	$SPADYT$	1	$SPBEYT$	1	$SQCZT$	3	Total	6	M1 A1 A1 A1 A1	One correct flow, including value 2 <sup>nd</sup> correct flow, including value 3 <sup>rd</sup> correct flow, including value  All correct, including values, that must total to 6 (there are other correct flows equivalent to these flows)  Must have scored at least M1A1 in (b)
Route	Flow															
$SPAXT$	1															
$SPADYT$	1															
$SPBEYT$	1															
$SQCZT$	3															
Total	6															
(d)	Max flow = 64 Cut through $AX, DX, DY, BE, QC$	A1 B1 B1	5													
			2	Must be listed												
	Total		11													

**Notes:**

(c) The  $SQC_T$  flow can only score 1 mark, even if it is split into 2 or 3 augmentations of 1  
The options should follow the following pattern (in any order)

Route	Flow
$S\_AXT$	1
$S\_DYT$	1
$S\_BE\_T$	1
$SQC\_T$	3
<b>Total</b>	6