

Version



**General Certificate of Education (A-level)
January 2013**

Mathematics

MD02

(Specification 6360)

Decision 2

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner 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 examiners 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 examiner understands and applies it in the same correct way. As preparation for standardisation each examiner 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, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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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.

Q	Solution	Marks	Total	Comments																								
1(a)		M1 A1 M1 A1	4	Forward pass, correct at two of <i>D, E, F</i> All correct Backward pass, correct at <i>G AND H</i> ft All correct																								
(b)	<table border="1"> <thead> <tr> <th>Activity</th> <th>Predecessor</th> </tr> </thead> <tbody> <tr><td>A</td><td>–</td></tr> <tr><td>B</td><td>–</td></tr> <tr><td>C</td><td>B</td></tr> <tr><td>D</td><td>A, C</td></tr> <tr><td>E</td><td>C</td></tr> <tr><td>F</td><td>B, C</td></tr> <tr><td>G</td><td>D, E</td></tr> <tr><td>H</td><td>E, F</td></tr> <tr><td>I</td><td>G, H</td></tr> <tr><td>J</td><td>G, H</td></tr> <tr><td>K</td><td>I, J</td></tr> </tbody> </table>	Activity	Predecessor	A	–	B	–	C	B	D	A, C	E	C	F	B, C	G	D, E	H	E, F	I	G, H	J	G, H	K	I, J	B1 B1	2	6+ correct All correct
Activity	Predecessor																											
A	–																											
B	–																											
C	B																											
D	A, C																											
E	C																											
F	B, C																											
G	D, E																											
H	E, F																											
I	G, H																											
J	G, H																											
K	I, J																											
(c)	(Critical) <i>B C F H I K</i>	B1	1																									
(d)	(Float <i>E</i>) 6 (hrs)	B1	1																									
(e)		M1 A1 A1 B1	3	Their critical activities and 3 others shown Critical activities and 3 others correct All correct, condone floats seen																								
(f)	34 (hrs)	B1	1																									
(g)	62 (hrs)	B1	1																									
	Total		13																									

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Q	Solution	Marks	Total	Comments
<p>2(a)</p>	<p style="text-align: right;">Min</p> $\begin{pmatrix} 4 & -1 & 2 & 3 \\ 4 & 6 & 3 & 7 \\ 1 & 3 & -2 & 4 \end{pmatrix} \begin{matrix} -1 \\ 3 \\ -2 \end{matrix}$ <p>Max $\begin{matrix} 4 & 6 & 3 & 7 \end{matrix}$</p> <p>Maximin (row) = 3</p> <p>Minimax (col) = 3</p> <p>As Maximin (row) = Minimax (col) There is a stable solution</p> <p>(Play safe) (H) $\left. \begin{matrix} B \\ F \end{matrix} \right\}$ (Play safe) (W) $\left. \begin{matrix} B \\ F \end{matrix} \right\}$</p>	<p>M1</p> <p>A1 CSO</p> <p>E1</p> <p>B1</p> <p>B1</p>	<p></p> <p></p> <p></p> <p>4</p> <p>1</p>	<p>Either correct, including correct values</p> <p>Both correct, written as equations PI by next line</p> <p>Must have equation and statement and scored first 2 marks</p> <p>Both correct</p>
<p>(b)</p>	<p>Saddle point (B, F)</p>	<p>B1</p>	<p>1</p>	
	Total		5	

MD02

Q	Solution	Marks	Total	Comments
3(a)	$\begin{pmatrix} 8 & 5 & 0 & 9 & 6 \\ 5 & 6 & 5 & 9 & 7 \\ 11 & 10 & 12 & 12 & 11 \\ 9 & 5 & 8 & 12 & 9 \end{pmatrix}$	B1	1	
(b)	Add an extra row ≥ 12	B1		
	$\begin{pmatrix} 8 & 5 & 0 & 9 & 6 \\ 5 & 6 & 5 & 9 & 7 \\ 11 & 10 & 12 & 12 & 11 \\ 9 & 5 & 8 & 12 & 9 \\ 12 & 12 & 12 & 12 & 12 \end{pmatrix} \begin{matrix} (0) \\ (5) \\ (10) \\ (5) \\ (12) \end{matrix}$			
	$\begin{matrix} 8 & 5 & 0 & 9 & 6 \\ 0 & 1 & 0 & 4 & 2 \\ 1 & 0 & 2 & 2 & 1 \\ 4 & 0 & 3 & 7 & 4 \\ 0 & 0 & 0 & 0 & 0 \end{matrix}$	M1		3 rows correct from row reduction
		A1		All correct
	$\begin{pmatrix} 8 & 5 & 0 & 9 & 6 \\ 0 & 1 & 0 & 4 & 2 \\ 1 & 0 & 2 & 2 & 1 \\ 4 & 0 & 3 & 7 & 4 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$ <p>(Zeros correctly covered by 4 lines)</p>	B1F		<p>Alternatives</p> $\begin{pmatrix} 8 & 5 & 0 & 9 & 6 \\ 0 & 1 & 0 & 4 & 2 \\ 1 & 0 & 2 & 2 & 1 \\ 4 & 0 & 3 & 7 & 4 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$
	Covered in 4 lines, not optimal (reduce by 1)	E1		*
	$\begin{matrix} 8 & 5 & 0 & 8 & 5 \\ 0 & 1 & 0 & 3 & 1 \\ 1 & 0 & 2 & 1 & 0 \\ 4 & 0 & 3 & 6 & 3 \\ 1 & 1 & 1 & 0 & 0 \end{matrix}$	B1		$\begin{matrix} 7 & 5 & 0 & 8 & 5 \\ 0 & 2 & 1 & 4 & 2 \\ 0 & 0 & 2 & 1 & 0 \\ 3 & 0 & 3 & 6 & 3 \\ 0 & 1 & 1 & 0 & 0 \end{matrix} \begin{matrix} (8) & (6) & (0) & (9) & (6) \\ (0) & (2) & (1) & (4) & (2) \\ (0) & (0) & (2) & (1) & (0) \\ (3) & (0) & (3) & (6) & (3) \\ (0) & (1) & (1) & (0) & (0) \end{matrix}$
	5 lines needed, optimal	(E1)		*or earned here
	Match WC, XA, YE, ZB, (-D)	B1		
	Value = 151	B1	8	
Total			9	

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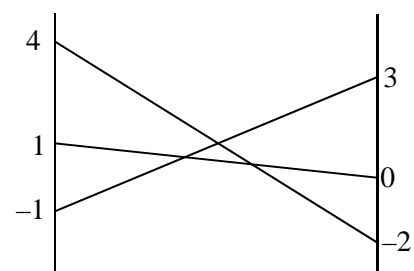
MD02

Q	Solution	Marks	Total	Comments
(4)(a)(i)	Max Flow = 50 (Min cut = 50)	E1		Either statement
(ii)	$35 \leq \text{max flow} \leq 50$ (or min cut)	E1, E1		E1 for strict inequalities
(iii)	Error or contradiction	E1	4	oe
(b)	At F ,			
	$\left. \begin{array}{l} \text{flow in} \geq 8 \\ \text{flow out} \leq 7 \end{array} \right\}$	M1 A1	2	Stating F and one of the 'flows'
	Total		6	

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Q	Solution	Marks	Total	Comments			
5(a)	$\begin{array}{cccccccc c} P & x & y & z & r & s & t & & \text{value} \\ 1 & -1 & 2 & -3 & 0 & 0 & 0 & & 0 \\ 0 & 1 & 1 & 1 & 1 & 0 & 0 & & 16 \\ 0 & 1 & -2 & 2 & 0 & 1 & 0 & & 17 \\ 0 & 2 & -1 & 2 & 0 & 0 & 1 & & 19 \end{array}$	B2,1,0	2	All correct, 3 rows correct			
	<p>(b)(i) z-col: $\frac{16}{1}, \frac{17}{2}, \frac{19}{2}$ Min, R_3 as pivot</p>				M1	2	
	A1						
	<p>(ii) $\begin{array}{cccccccc c} 1 & \frac{1}{2} & -1 & 0 & 0 & 1\frac{1}{2} & 0 & & \frac{51}{2} \\ 0 & \frac{1}{2} & 2 & 0 & 1 & -\frac{1}{2} & 0 & & \frac{15}{2} \\ 0 & \frac{1}{2} & -1 & 1 & 0 & \frac{1}{2} & 0 & & \frac{17}{2} \\ 0 & 1 & 1 & 0 & 0 & -1 & 1 & & 2 \end{array}$</p> <p>Alternative</p> $\begin{array}{cccccccc c} 2 & 1 & -2 & 0 & 0 & 3 & 0 & & 51 \\ 0 & 1 & 4 & 0 & 2 & -1 & 0 & & 15 \\ 0 & 1 & -2 & 2 & 0 & 1 & 0 & & 17 \\ 0 & 1 & 1 & 0 & 0 & -1 & 1 & & 2 \end{array}$				M1	3	Row operations
A1	One row (other than R_3) correct						
A1	All correct						
(c)(i)	<p>y col $\frac{15}{4}, \left(-\frac{17}{2}\right), \frac{2}{1}$ R_4 as pivot</p>	B1	3	Fully correct description			
	$\begin{array}{cccccccc c} 1 & 1\frac{1}{2} & 0 & 0 & 0 & \frac{1}{2} & 1 & & \frac{55}{2} \\ 0 & -1\frac{1}{2} & 0 & 0 & 1 & 1\frac{1}{2} & -2 & & \frac{7}{2} \\ 0 & 1\frac{1}{2} & 0 & 1 & 0 & -\frac{1}{2} & 1 & & \frac{21}{2} \\ 0 & 1 & 1 & 0 & 0 & -1 & 1 & & 2 \end{array}$	M1		Row operations			
	<p>Alternative</p> $\begin{array}{cccccccc c} 2 & 3 & 0 & 0 & 0 & 1 & 2 & & 55 \\ 0 & -3 & 0 & 0 & 2 & 3 & -4 & & 7 \\ 0 & 3 & 0 & 2 & 0 & -1 & 2 & & 21 \\ 0 & 1 & 1 & 0 & 0 & -1 & 1 & & 2 \end{array}$	(M1)			All correct		
	(A1)						
(c)(ii)	<p>Optimal</p> $P = \frac{55}{2}$ $x=0, y=2, z=\frac{21}{2}$ $s=t=0, r=\frac{7}{2}$	B1	3	Both statement and value needed. OE			
	B1						
	B1						
Total			13				

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Q	Solution	Marks	Total	Comments
6(a)	$R_C > R_B$	E1	1	oe
(b)	$A \begin{pmatrix} -2 & 0 & 3 \\ 4 & 1 & -1 \end{pmatrix}$ $C \begin{pmatrix} -2 & 0 & 3 \\ 4 & 1 & -1 \end{pmatrix}$ <p>K plays A prob p C prob $1-p$</p> <p>P plays</p> $\left. \begin{array}{l} D, K \text{ wins } -2p + 4(1-p) \quad (= 4 - 6p) \\ E, K \text{ wins } 1-p \\ F, K \text{ wins } 3p - 1(1-p) \quad (= -1 + 4p) \end{array} \right\}$  <p>Max at $1-p = -1+4p$</p> $p = \frac{2}{5}$ <p>$(K \text{ plays}) A \text{ prob } \frac{2}{5}, C \text{ prob } \frac{3}{5}$</p> <p>Value of game = $\frac{3}{5}$</p>	<p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>B1</p>	<p>1</p> <p>7</p>	<p>Allow 2 expressions in unsimplified form All 3 correct</p> <p>Must have 3 lines</p> <p>With values shown</p> <p>Identifying correct maximum from their graph</p> <p>Both stated, coming from equating correct two equations and M2 scored</p>

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Q	Solution	Marks	Total	Comments
<p>6(c)</p>	<p>P plays D prob p E " q F " $1-p-q$</p> <p>K plays A, P loses $-2p + 3(1-p-q) = 3 - 5p - 3q$</p> <p>$K$ plays C, P loses $4p + q - 1(1-p-q) = -1 + 5p + 2q$</p> <p>$3 - 5p - 3q = \frac{3}{5}$ $-1 + 5p + 2q = \frac{3}{5}$</p> <hr/> <p>$2 - q = \frac{6}{5}$ $q = \frac{4}{5}$</p> <p>$5p + \frac{8}{5} - 1 = \frac{3}{5}$ $p = 0$</p> <p>P plays D prob 0 E, prob $\frac{4}{5}$ F, prob $\frac{1}{5}$</p> <p>Alternative method Probability of D is 0 $3(1-p) = \frac{3}{5}$ or $p - 1(1-p) = \frac{3}{5}$ $p = \frac{4}{5}$ E prob $\frac{4}{5}$ F prob $\frac{1}{5}$</p>	<p>M1</p> <p>m1</p> <p>A1 CSO</p> <p>E1</p> <p>(E1) (M1) (m1) (A1) CSO</p>	<p>4</p>	<p>Either (unsimplified) expression correct</p> <p>Equating BOTH of their expressions to value of their game</p> <p>Or for finding p</p> <p>All three needed, must have scored previous A mark</p> <p>OE, might be earned in final line</p> <p>Or equating the expressions</p>
	Total		12	

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Q	Solution				Marks	Total	Comments
7(a)	Stage	State	From	Value			
	1	<i>G</i>	<i>I</i>	15			
		<i>H</i>	<i>I</i>	12			
	--	--	--	--			
	2	<i>E</i>	<i>G</i>	15+15 = 30 ←			
			<i>H</i>	12+16 = 28			
		<i>F</i>	<i>G</i>	15+13=28			
			<i>H</i>	12+17= 29 ←			
	--	--	--	-- -- --			
	3	<i>B</i>	<i>E</i>	30+16 = 46			
		<i>C</i>	<i>E</i>	30+14 = 44 ←			
			<i>F</i>	29+12 = 41			
		<i>D</i>	<i>F</i>	29+15 = 44			
	--	--	--	-- -- --			
	4	<i>A</i>	<i>B</i>	46+12 = 58			
			<i>C</i>	44+20= 64 ←			
			<i>D</i>	44+18 = 62			
(b)	Route <i>A C E G I</i>				B1	7	Stage 2 values correct Calculating 4 values at stage 3 Using max values at <i>E</i> and <i>F</i> All 4 values correct Using max at <i>C</i> All correct Identifying 64 as maximum value
Total						8	

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Q	Solution	Marks	Total	Comments
(8)(a)	<p> $ABEH$ 8 $ACFH$ 5 $ADGH$ 11 </p>	B1	1	
(b)(i)	<p> $ACEH$ 2 $ACGH$ 4 Either $ADFH$ 1 and $ABFH$ 2 Or $ADFH$ 3 </p>	M1 A1 A1		One correct route and flow At least one other correct All correct
		M1		Forward and back flows on diagram
(ii)	<p>Max flow 33</p>	A1 B1	5	All correct
(c)	<p>Cut through BE, CE, FH, CG, DG</p>	B1	2	OE
		B1	1	
Total			9	
TOTAL			75	