



## **General Certificate of Education**

# **Mathematics 6360**

**MDO2      Decision 02**

## **Mark Scheme**

*2008 examination - January series*

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 meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' 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.

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### Key to mark scheme and abbreviations used in marking

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	MC	mis-copy
CAO	correct answer only	MR	mis-read
CSO	correct solution only	RA	required accuracy
AWFW	anything which falls within	FW	further work
AWRT	anything which rounds to	ISW	ignore subsequent work
ACF	any correct form	FIW	from incorrect work
AG	answer given	BOD	given benefit of doubt
SC	special case	WR	work replaced by candidate
OE	or equivalent	FB	formulae book
A2,1	2 or 1 (or 0) accuracy marks	NOS	not on scheme
-x EE	deduct x marks for each error	G	graph
NMS	no method shown	c	candidate
PI	possibly implied	sf	significant figure(s)
SCA	substantially correct approach	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. However, there are situations in some units where part marks would be appropriate, particularly when similar techniques are involved. Your Principal Examiner will alert you to these and details will be provided on the mark scheme.

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**.

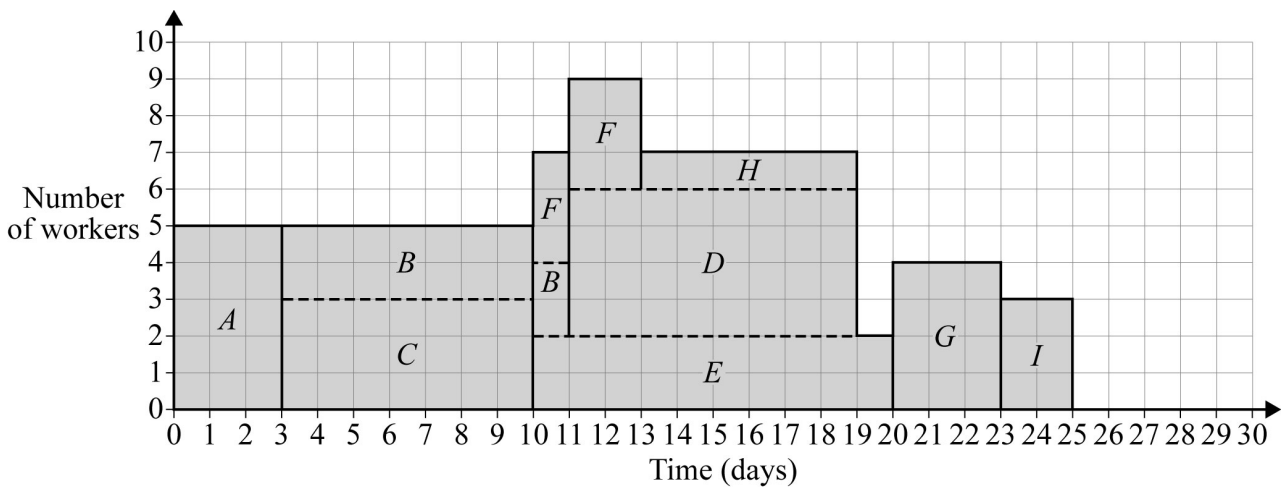
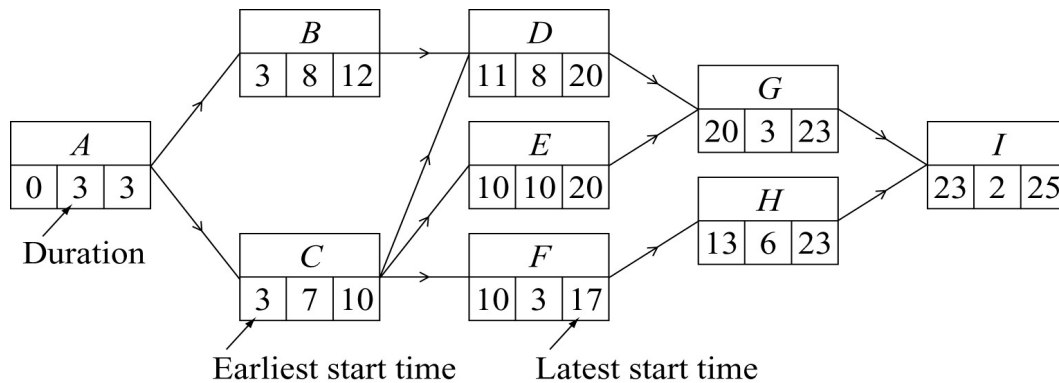
Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

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.**

MD02

Q	Solution	Marks	Total	Comments
1(a)	<i>G, H and I</i> in correct place	M1	2	See below
	Lines (with arrows) correct	A1		
	Forward pass (no more than 1 error FT)	M1	4	
	Early start times correct	A1		
	Backward pass (no more than 1 error FT)	M1		
Latest finish times correct	A1			
(c)	Correct critical path: <i>ACEGI</i> Correct minimum time: 25 days	B1 B1	2	
(d)	“Their” critical activities	B1 <sup>√</sup>	4	See below  CSO
	Block $0 \leq t \leq 10$	B1		
	$10 \leq t \leq 11$	B1		
(e)	All correct including labels	B1	3	
	Problem with <i>F</i> or day 11	M1		
	Delay start of <i>D</i> (by 2 days), then <i>G</i> and <i>I</i> (by 1 day) Extra time 1 day	A1 B1		
<b>Total</b>			<b>15</b>	



## MD02 (cont)

Q	Solution					Marks	Total	Comments	
2(a)		Ash	Bob	Col	Dan	Emma			
	Task 1	14	10	12	12	14			
	Task 2	11	13	10	12	12			
	Task 3	13	11	12	**	12			
	Task 4	13	10	12	13	15			
	15	15	15	15	15	B1	1	Extra row of equal non-zero values (expect 15, 15, ...)	
(b)		Ash	Bob	Col	Dan	Emma			
	Task 1	3	0	2	0	2	M1		Attempt to reduce columns
	Task 2	0	3	0	0	0			
	Task 3	2	1	2	**	0	A1		Correct
	Task 4	2	0	2	1	3			Final row may be different
	4	5	5	3	3				
		Ash	Bob	Col	Dan	Emma			
Task 1	3	0	2	0	2	A1		Reduce rows correct	
Task 2	0	3	0	0	0				
Task 3	2	1	2	**	0				
Task 4	2	0	2	1	3				
	1	2	2	0	0	B1		Zeros can be covered with 4 lines (shown)	
		Ash	Bob	Col	Dan	Emma			
Task 1	2	0	1	0	2	M1		Adjustment	
Task 2	0	4	0	1	1			reducing uncovered elements by 1 and increasing double uncovered by 1	
Task 3	1	1	1	**	0				
Task 4	1	0	1	1	3				
	0	2	1	0	0	A1		Correct	
	Matching E3, B4, C2, D1					B1			
	Total time 44 min					B1	8		
(c)	No, time cannot be improved					B1			
	** became 0 from 2 <sup>nd</sup> tableau onwards								
	B must take task 4 $\Rightarrow$ D must ...					E1	2	Or other correct reasoning	
<b>Total</b>							<b>11</b>		

**MD02 (cont)**

Q	Solution	Marks	Total	Comments															
<b>3(a)</b>	Rob's gain = Con's loss (at each entry of matrix)	E1	1	Zero-sum explained Rob's winnings + Con's winnings = 0 (for every pair of strategies)															
<b>(b)</b>	<table style="margin-left: auto; margin-right: auto; border-collapse: collapse;"> <tr> <td></td> <td style="border-right: 1px solid black; padding: 5px;">-2</td> <td style="border-right: 1px solid black; padding: 5px;">5</td> <td style="border-right: 1px solid black; padding: 5px;">3</td> <td style="padding: 5px; text-align: center;">min <span style="border: 1px solid black; padding: 2px;">-2</span></td> </tr> <tr> <td style="border-right: 1px solid black; padding: 5px;"></td> <td style="border-right: 1px solid black; padding: 5px;">3</td> <td style="border-right: 1px solid black; padding: 5px;">-3</td> <td style="border-right: 1px solid black; padding: 5px;">-1</td> <td style="padding: 5px; text-align: center;">-3</td> </tr> <tr> <td style="border-right: 1px solid black; padding: 5px; text-align: right;">max</td> <td style="border-right: 1px solid black; padding: 5px;"><span style="border: 1px solid black; padding: 2px;">3</span></td> <td style="border-right: 1px solid black; padding: 5px;">5</td> <td style="border-right: 1px solid black; padding: 5px;"><span style="border: 1px solid black; padding: 2px;">3</span></td> <td style="padding: 5px; text-align: center;">-3</td> </tr> </table>		-2	5	3	min <span style="border: 1px solid black; padding: 2px;">-2</span>		3	-3	-1	-3	max	<span style="border: 1px solid black; padding: 2px;">3</span>	5	<span style="border: 1px solid black; padding: 2px;">3</span>	-3	B1		min of rows and max of columns All values correct (seen)
	-2	5	3	min <span style="border: 1px solid black; padding: 2px;">-2</span>															
	3	-3	-1	-3															
max	<span style="border: 1px solid black; padding: 2px;">3</span>	5	<span style="border: 1px solid black; padding: 2px;">3</span>	-3															
	$-2 \neq 3$ $\Rightarrow$ no stable solution	M1		maximin = -2 minimax = 3 } either correct															
		E1	3																
<b>(c)</b>	$R_3$ dominated by $R_1$ $(-3, 3, 2) < (-2, 5, 3)$ so never play $R_3$	E1	1																
<b>(d)(i)</b>	Choose $R_1$ with probability $p$ and $R_2$ with probability $1 - p$  Expected gain when C plays: $C_1: -2p + 3(1 - p) = 3 - 5p$ $C_2: 5p - 3(1 - p) = 8p - 3$ $C_3: 3p - (1 - p) = -1 + 4p$	M1		Attempt at one expression															
		A1		All correct unsimplified															
		M1		Plotting expected gain for $0 \leq p \leq 1$															
		A1		Correct with values at $p = 0$ and $p = 1$ clear															
	$3 - 5p = 8p - 3$	M1		Choosing $C_1$ and $C_2$ intersection or their highest point															
	$\Rightarrow p = \frac{6}{13}$	A1																	
	Play $R_1$ with probability $\frac{6}{13}$ and $R_2$ with probability $\frac{7}{13}$	E1 $\checkmark$	7	FT their $p$ (statement needed)															
<b>(ii)</b>	Value of game = $3 - \frac{30}{13}$ $= \frac{9}{13}$	B1	1	Or $\frac{48}{13} - 3$ $= \frac{9}{13}$															
<b>Total</b>			<b>13</b>																

## MD02 (cont)

Q	Solution	Marks	Total	Comments																																								
<b>4(a)</b>	$x + z \leq 9$	M1	2	One correct inequality or all using <																																								
	$2x + y + 4z \leq 40$ $4x + 2y + 3z \leq 33$	A1		All correct																																								
<b>(b)(i)</b>	Pivot is <b>1</b> in $z$ -column	M1	4	May be implied by use																																								
	<table border="1"> <thead> <tr> <th><math>P</math></th> <th><math>x</math></th> <th><math>y</math></th> <th><math>z</math></th> <th><math>s</math></th> <th><math>t</math></th> <th><math>u</math></th> <th>value</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>3</td> <td>-3</td> <td>0</td> <td>5</td> <td>0</td> <td>0</td> <td>45</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> <td><b>1</b></td> <td>1</td> <td>0</td> <td>0</td> <td>9</td> </tr> <tr> <td>0</td> <td>-2</td> <td>1</td> <td>0</td> <td>-4</td> <td>1</td> <td>0</td> <td>4</td> </tr> <tr> <td>0</td> <td>1</td> <td>2</td> <td>0</td> <td>-3</td> <td>0</td> <td>1</td> <td>6</td> </tr> </tbody> </table>	$P$		$x$	$y$	$z$	$s$	$t$	$u$	value	1	3	-3	0	5	0	0	45	0	1	0	<b>1</b>	1	0	0	9	0	-2	1	0	-4	1	0	4	0	1	2	0	-3	0	1	6	A1	One row correct (other than pivot)
	$P$	$x$		$y$	$z$	$s$	$t$	$u$	value																																			
	1	3		-3	0	5	0	0	45																																			
	0	1		0	<b>1</b>	1	0	0	9																																			
0	-2	1	0	-4	1	0	4																																					
0	1	2	0	-3	0	1	6																																					
		A1	Another row correct (other than pivot)																																									
		A1	All correct																																									
		A1	All correct																																									
<b>(ii)</b>	(Know optimal value <b>not</b> reached) since $-3$ in <u>top row</u>	E1	1																																									
<b>(c)(i)</b>	<table border="1"> <tbody> <tr> <td>1</td> <td><math>4\frac{1}{2}</math></td> <td>0</td> <td>0</td> <td><math>\frac{1}{2}</math></td> <td>0</td> <td><math>\frac{3}{2}</math></td> <td>54</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>9</td> </tr> <tr> <td>0</td> <td><math>-2\frac{1}{2}</math></td> <td>0</td> <td>0</td> <td><math>-2\frac{1}{2}</math></td> <td>1</td> <td><math>-\frac{1}{2}</math></td> <td>1</td> </tr> <tr> <td>0</td> <td><math>\frac{1}{2}</math></td> <td><b>1</b></td> <td>0</td> <td><math>-\frac{3}{2}</math></td> <td>0</td> <td><math>\frac{1}{2}</math></td> <td>3</td> </tr> </tbody> </table>	1	$4\frac{1}{2}$	0	0	$\frac{1}{2}$	0	$\frac{3}{2}$	54	0	1	0	1	1	0	9	0	$-2\frac{1}{2}$	0	0	$-2\frac{1}{2}$	1	$-\frac{1}{2}$	1	0	$\frac{1}{2}$	<b>1</b>	0	$-\frac{3}{2}$	0	$\frac{1}{2}$	3	M1	4	Next pivot <b>2</b> in $y$ -column and perhaps divide by 2									
	1	$4\frac{1}{2}$	0	0	$\frac{1}{2}$	0	$\frac{3}{2}$	54																																				
	0	1	0	1	1	0	9																																					
	0	$-2\frac{1}{2}$	0	0	$-2\frac{1}{2}$	1	$-\frac{1}{2}$	1																																				
	0	$\frac{1}{2}$	<b>1</b>	0	$-\frac{3}{2}$	0	$\frac{1}{2}$	3																																				
		A1	One row correct (other than pivot)																																									
		A1	Another row correct																																									
		A1	All correct																																									
		A1	All correct																																									
<b>(ii)</b>	Optimum value of $P$ now reached	E1✓	3	FT statement if their tableau has negative values in top row																																								
	$P = 54, x = 0, y = 3, z = 9$	B1✓																																										
	$s = 0, t = 1, u = 0$	B1			All correct and final tableau correct																																							
	<b>Total</b>		<b>14</b>																																									

## MD02 (cont)

Q	Solution				Marks	Total	Comments
5(a)	Stage	State	From	Value	B1		Stage 2 values correct
	1	<i>H</i>	<i>T</i>	5 *			
		<i>I</i>	<i>T</i>	6 *			
	2	<i>F</i>	<i>H</i>	$-2 + 5 = 3$ *			
			<i>T</i>	4			
			<i>I</i>	$-2 + 6 = 4$			
		<i>G</i>	<i>I</i>	$5 + 6 = 11$ *			
	M1	3	<i>C</i>	<i>H</i>	$4 + 5 = 9$		
				<i>F</i>	$5 + 3 = 8$ *		
				<i>G</i>	$2 + 11 = 13$		
			<i>D</i>	<i>G</i>	$-1 + 11 = 10$ *		
	A1		<i>E</i>	<i>F</i>	$5 + 3 = 8$ *		
				<i>G</i>	$3 + 11 = 14$		
	M1	4	<i>A</i>	<i>C</i>	$2 + 8 = 10$		
			<i>D</i>	$-1 + 10 = 9$ *			
		<i>B</i>	<i>D</i>	$-2 + 10 = 8$			
A1			<i>E</i>	$-3 + 8 = 5$ *			
A1	5	<i>S</i>	<i>A</i>	$1 + 9 = 10$ *			
			<i>B</i>	$5 + 5 = 10$ *			
(b)	Minimum cost 10				B1	6	Stage 5 correct CSO
	Routes <i>SBEFHT</i>				B1		
	<i>SADGIT</i>				B1		
<b>Total</b>					<b>9</b>		



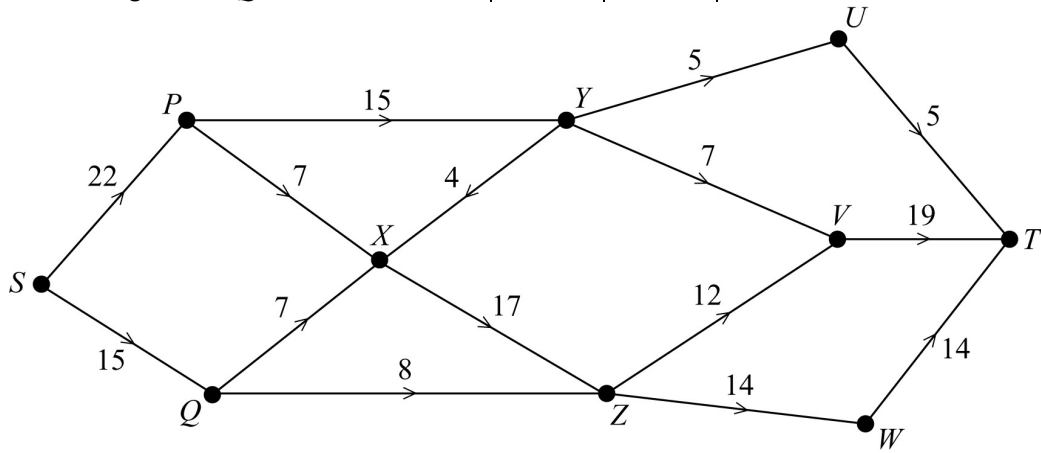
MD02 (cont)

Q	Solution	Marks	Total	Comments
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6(a) Correct position of *S* and *T*  
 Values on edges *SP*, *SQ*, *UT*, *VT* and *WT*

M1  
 A1

2



(b)(i) Cut *C* has value 40

B1

1

15 + 0 + 17 + 8

(ii) Max flow ≤ 40

E1

1

(c)

Route	Flow
<i>SQZWT</i>	8
<i>SPYZVT</i>	4

B1

B1

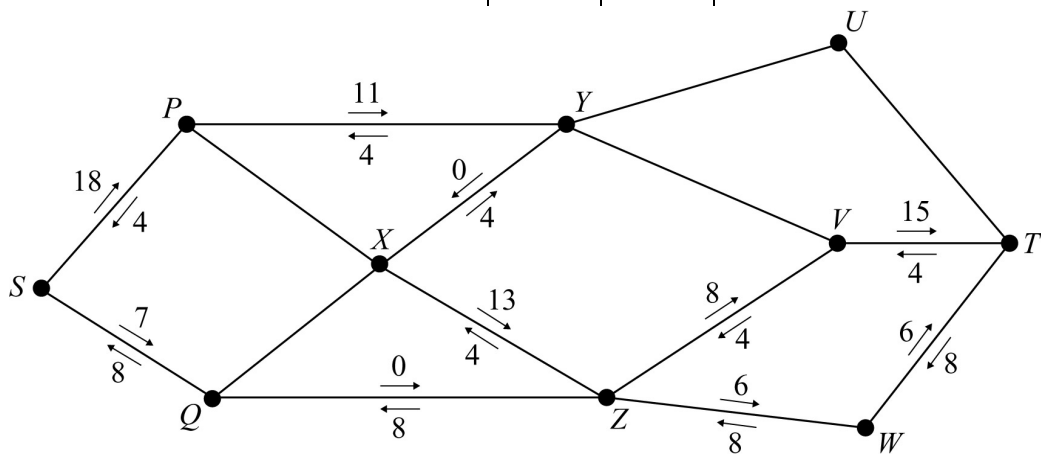
2

(d)(i) 3 forward and backward flows correct  
 All initial values correct on edges below

M1

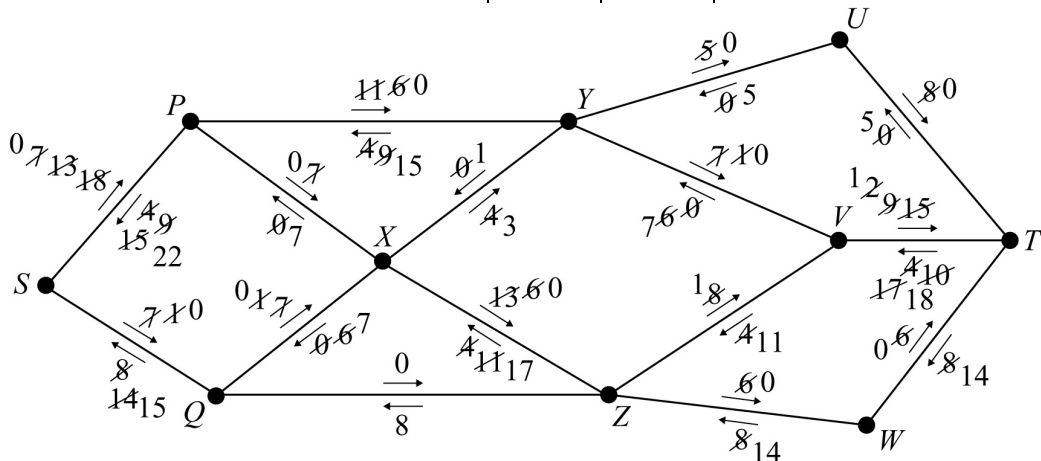
A1

2



MD02 (cont)

Q	Solution	Marks	Total	Comments																
6(d)(ii)	<table border="1"> <thead> <tr> <th>Route</th> <th>Flow</th> </tr> </thead> <tbody> <tr> <td><i>SQZWT</i></td> <td>8</td> </tr> <tr> <td><i>SPYXZVT</i></td> <td>4</td> </tr> <tr> <td><i>SPYUT</i></td> <td>5</td> </tr> <tr> <td><i>SPYVT</i></td> <td>6</td> </tr> <tr> <td><i>SPXZVT</i></td> <td>7</td> </tr> <tr> <td><i>SQXZWT</i></td> <td>6</td> </tr> <tr> <td><i>SQXYVT</i></td> <td>1</td> </tr> </tbody> </table>	Route	Flow	<i>SQZWT</i>	8	<i>SPYXZVT</i>	4	<i>SPYUT</i>	5	<i>SPYVT</i>	6	<i>SPXZVT</i>	7	<i>SQXZWT</i>	6	<i>SQXYVT</i>	1			(Many different possibilities)
	Route	Flow																		
	<i>SQZWT</i>	8																		
	<i>SPYXZVT</i>	4																		
	<i>SPYUT</i>	5																		
	<i>SPYVT</i>	6																		
	<i>SPXZVT</i>	7																		
<i>SQXZWT</i>	6																			
<i>SQXYVT</i>	1																			
		M1		2 or more correct flows in table																
		A1		Table correct (adding to 37)																
		M1		At least 2 flows augmented on diagram																
		A1	4	Correct forward and backward final flows																



(e)	Flow from Y to X is 3	B1	1	Other possibility for ZV, VT, ZW and WT
	<b>Total</b>		<b>13</b>	
	<b>TOTAL</b>		<b>75</b>	