AQA Maths Decision 2

Mark Scheme Pack

2006-2015

Version 1.0: 0106

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2006 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.

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.

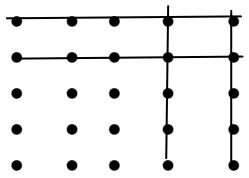
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

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

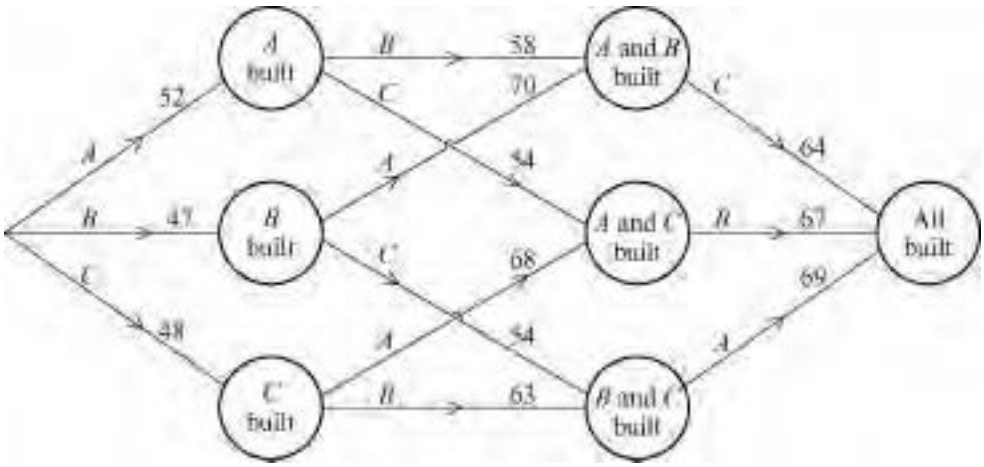
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

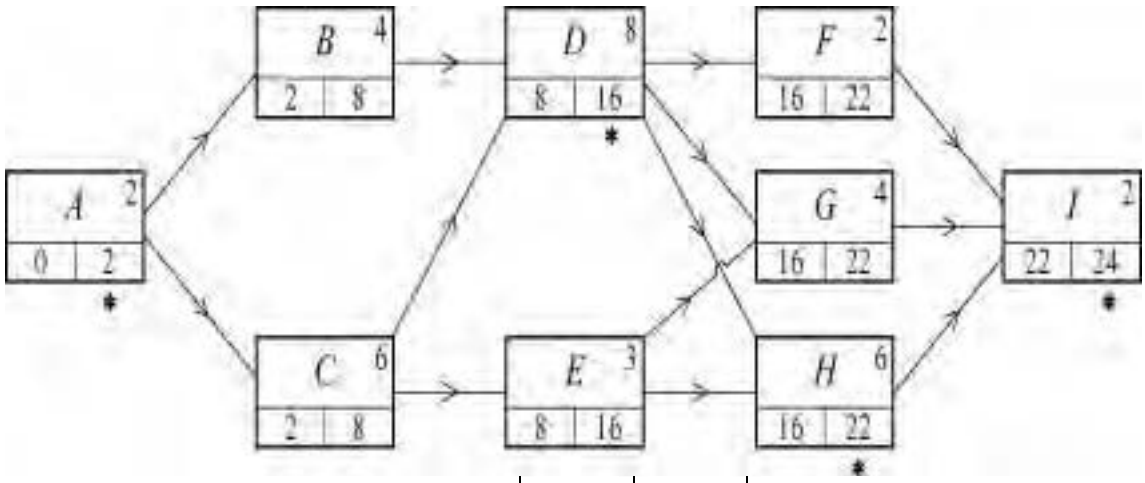
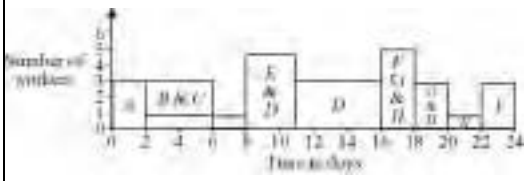
MD02

Q	Solution	Marks	Total	Comments
1(a)	Add extra row with all values the same	B1	1	Usually all equal to 26 and below the other rows
(b)	Reduce columns first 0 0 0 4 4 6 2 2 5 5 5 3 5 0 4 4 2 3 2 0 10 7 8 5 6	M1 A1		26 26 26 26 26 16 19 18 25 24 22 21 20 26 25 21 22 23 21 24 20 21 21 23 20 26 26 26 26 26
	Reduce rows 0 0 0 4 4 4 0 0 3 3 5 3 5 0 4 4 2 3 2 0 5 2 3 0 1	M1 A1	4	These 2 marks available for those who reduce rows first
	Covering zeros requires 4 lines so adjust with least entry remaining being 2	M1		
	[0] 0 0 6 6 4 0 [0] 5 5 3 1 3 [0] 4 2 0 1 2 [0] 3 [0] 1 0 1	A1	2	Other solutions possible here
	Match *A*– 1; *C* = 2; *D*–3; *E*–4	B1		
	Expected minimum time 16 + 20 +21 + 20 = 77 min	B1	2	
	Total		**9**	

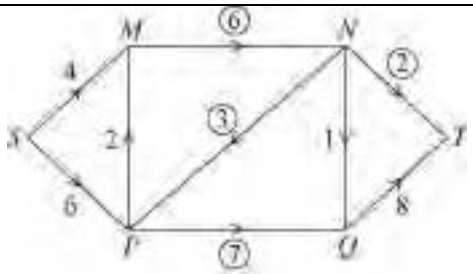
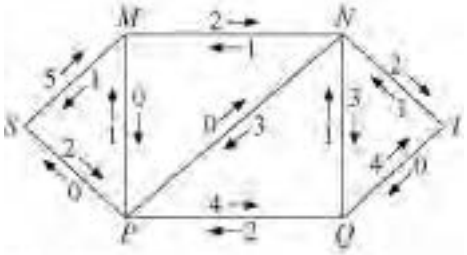
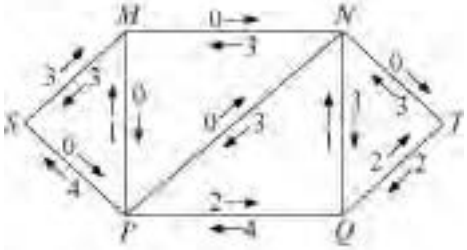
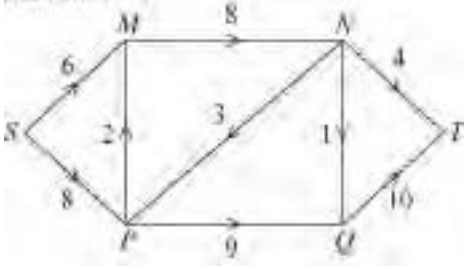
MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)				
	Network diagram	M1 A1	 2	SCA Correct
(b)	Clear attempt to use Dynamic Programming Working backwards through network			Complete enumeration M0 Forwards through network
	Month / Already Built / Machine Built / Profit / Total / (Max*) 3: *A* & *B* / *C* / 64 / 64* (Max*) *A* & *C* / *B* / 67 / 67* *B* & *C* / *A* / 69 / 69* 2: *A* / *B* / 58 / 58+64 =122* *A* / *C* / 54 / 54+67 =121 *B* / *A* / 70 / 70+64 =134* *B* / *C* / 54 / 54+69 =123 *C* / *A* / 68 / 68+67 =135* *C* / *B* / 63 / 63+69 = 132 1: – / *A* / 52 / 52+122 = 174 – / *B* / 47 / 47+134 = 181 – / *C* / 48 / 48+135 =183*	M1 M1 A1		*A* 52 52* *B* 47 47* *C* 48 48* *AB* 110 117 *AC* 106 116 six possibilities *BC* 101 111 Correct max identified and rest correct *BA* 117*; *CA* 116*; *CB* 111* Exactly 3 totals considered Considering previous max to combine
	The machine should therefore be built in the order *C* then *A* then *B*	A1 B1	5	*BAC* 181; *CAB* 183; *CBA* 180 Everything correct and route clearly traceable
	Max profit = £183000	B1	2	condone 183
	Total		**9**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)				
	Activity network SCA	M1 A1 A1	 3	 almost correct (up to 2 slips) all correct
(b)	Forward pass for earliest times	M1 A1	 2	
(c)	Backward pass	M1 A1	 2	
(d)	Critical path is ACDHI Minimum completion 24 days	B1 B1	 2	
(e)	Non-critical *B* *E* *F* *G* Float 2 5 4 2	M1 A1√	 2	At least 3 activities and float in one activity √ correct √ their earliest and latest times
(f)		M1 A1 M1 A1	 4	Histogram ≤ 11 Correct Rest as histogram – generally start activities ok All correct
	Resource histogram			
(g)	Problems with *D* & *E* solved by *E* coming after *D* Problem at 16-18 days with *F* can be solved by moving *F* to 20-22 Must overrun by equivalent to duration of *E* (3 days)	M1 A1 B1	 3	
	Total		**18**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)		B1 B1 B1 B1	4	*MN* *NT* *PQ* *NP*
(b)(i)		M1		initial flow indicated as surplus forward and backward flows
	e.g. SMNT 2 SPQT 2	M1 A1 A1		use of flow augmentation one flow correctly identified all possible flows correct
		M1 A1	6	amending flows (dep on first M1) final situation with saturation at *M* and *P*
(ii)	Max flow = 14 	B1 B1	2	
(c)	Cut through 2 of their saturated arcs $\left\{\begin{array}{c}\{S,M\}\ /\ \{P,N,Q,T\} \\ \text{or cuts through } MN,\ MP\ \ \&\ \ SP\end{array}\right\}$	M1 A1	2	cut on **original** network described or drawn
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)	Introducing slack variables	M1		
	P x y z r s value 1 –3 –2 –4 0 0 0 0 1 4 (2) 1 0 8 0 2 7 3 0 1 21	A2	3	–1 EE
(b)	Choosing correct pivot in z-column	M1		and perhaps dividing by 2
	1 –1 6 0 2 0 16 0 ($\frac{1}{2}$) 2 1 $\frac{1}{2}$ 0 4 0 $\frac{1}{2}$ 1 0 $-\frac{3}{2}$ 1 9	M1 A1	3	row operations correct
(c)(i)	Need to use x – column for pivot	M1		
	Choosing correct pivot	A1		
	1 0 10 2 3 0 24	M1		row operations
	0 1 4 2 1 0 8	A1		top row
	0 0 –1 –1 –2 1 5	A1	5	third row
(ii)	Yes optimal	B1√		
	No negative values in top row	E1	2	
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6 (a)	$(-2,2,4) < (2,4,5)$			
	So S_1 dominated by S_2	E1		
	$\begin{pmatrix}4\\5\\2\end{pmatrix} > \begin{pmatrix}2\\4\\1\end{pmatrix}$			note > sign
	So C_3 dominated by C_2	E1	2	
(b)	2×2 game now $\begin{array}{c} \\ S_2 \\ S_3 \end{array}\begin{array}{c} \begin{array}{cc} C_1 & C_2 \end{array} \\ \begin{bmatrix} 2 & 4 \\ 5 & 1 \end{bmatrix} \end{array}$			
	Minimum of rows $(2,4) = 2$	M1		correct method for either S or C
	Minimum of $(5,1) = 1$			
	Choose maximum = $\boxed{2}$	A1		play safe for Sam is S_2
	Max of column 1 = max (2,5) = 5 Max of column 2= max (4,1) = 4			
	Choose minimum = 4	A1		play safe for computer is C_2
	Since $2 \neq 4 \Rightarrow$ not stable solution	E1	4	
(c)(i)	Computer picks C_1			
	Expected game $= 2p + 5(1-p)$	M1		
	$= 5 - 3p$	A1		
	Computer picks C_2			
	Expected gain $= 4p + (1-p)$			
	$= 1 + 3p$	A1	3	
(ii)	Best mixed strategy			
	$5 - 3p = 1 + 3p$	M1		
	$\Rightarrow p = \frac{2}{3}$	A1	2	
(iii)	Expected points gain			
	$= 5 - 3\times\left(\frac{2}{3}\right)$			Or $1 + 3\left(\frac{2}{3}\right)$
	$= 3$	B1	1	
	Total		**12**	
	Total		**75**	

Version 1.0: 0706

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2006 examination – June 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.

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.

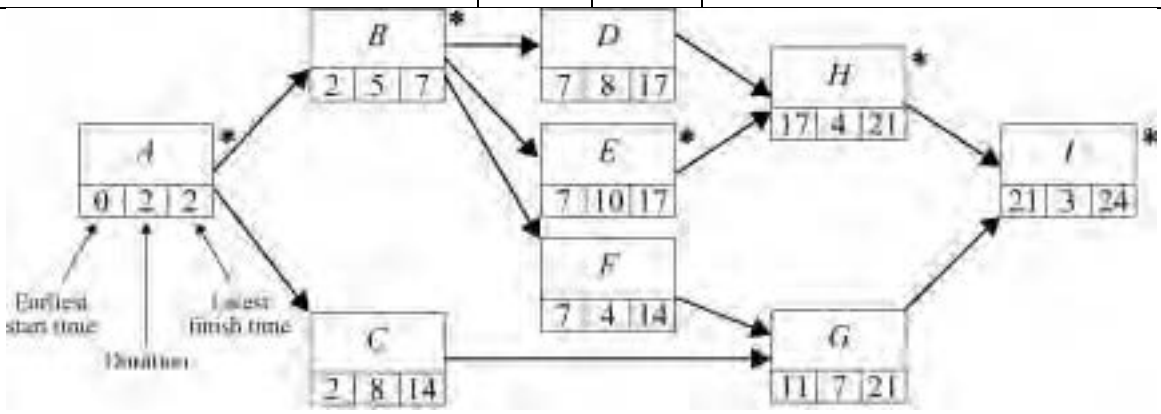
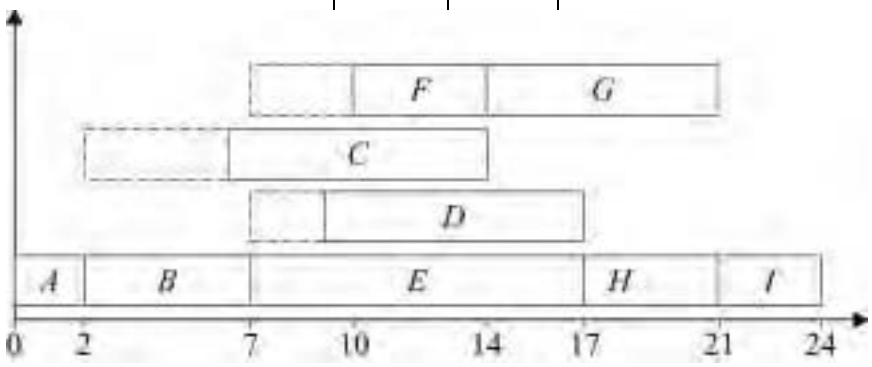
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

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

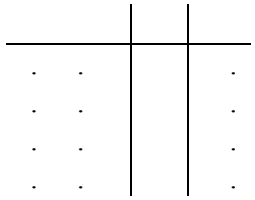
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

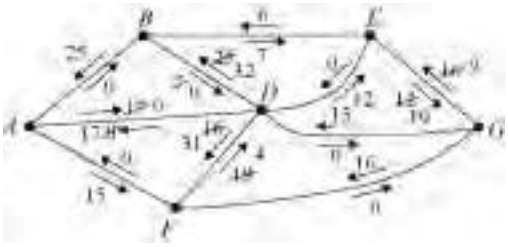
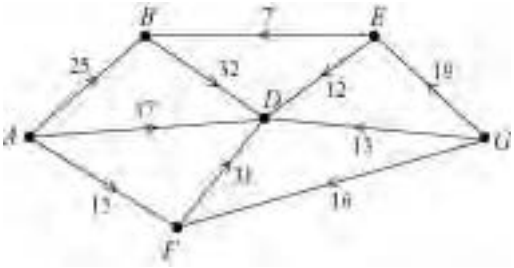
MD02

Q	Solution	Marks	Total	Comments
1(a)		M1 A1 A1	 3	SCA (almost correct 2 slips) Correct
(b)	Forward pass for earliest start times	M1 A1	 2	 All correct
(c)	Backward pass for latest finish times	M1 A1	 2	 All correct
(d)	Critical path *A B E H I*	B1	1	
(e)	Non critical: *C* 4, *D* 2, *F* 3, *G* 3 Float	M1 A1	 2	At least one float time correct All correct
(f)				
	'their' critical path on chart	B1√		
	C from 6 to 14 (with space 2-6)	M1		One other activity (condone no slack or earliest start)
	D from 9 to 17 (with slack 7-9)	A1		2 other non critical activities
	F & G from 10 to 21 with appropriate slack	A1	4	All correct
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	Add extra row with all values equal	B1	1	Usually + 25 and below rest 18 15 19 20 17 23 24 22 25 23 20 16 18 22 19 21 17 18 23 20 25 25 25 25 25
(b)	Reduce columns first P Q R S T A 0 0 1 0 0 B 5 9 4 5 6 C 2 1 0 2 2 D 3 2 0 3 3 (E) 7 10 7 5 8	M1 A1		Do not award if full row of zeros added
	Reduce rows next 0 0 1 0 0 1 5 0 1 2 2 1 0 2 2 3 2 0 3 3 2 5 2 0 3	M1 A1√		These 2 marks available for those who reduce row first  One error only
	Covering zeros requires 3 lines so adjust with least entry remaining being 1 P Q R S T A 0 0 2 1 0 R 0 4 0 1 1 C 1 0 0 2 1 D 2 1 0 3 2 E 1 4 2 0 2	M1 A1√ 		SC if full row of zeros, award M1 for further stage of adjustment and A1 for final correct matrix ft one error only
	Match: A-Tim; B-Phil; C-Quin; D-Ros	B1		
	Min^{m} Time $= 17 + 23 + 16 + 18 = 74$ secs	B1	8	
	Total		**9**	

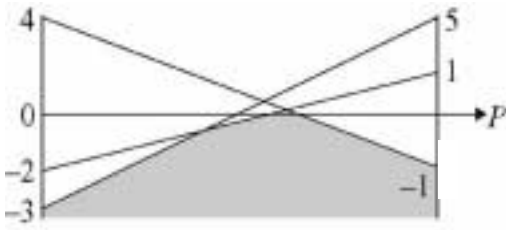
MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	Working back from H Starting from *A* (network)			Alternatively, from A
	B 8^1 *F* ~~5^2~~ 4^3	B1 M1		First (stage) costs second stage attempt
	C ~~7^1~~ 6^2 *H* ~~16^2~~ 14^4 14^5	M1 M1		second stage indicated eg 15^2 etc Third stage attempt (two numbers crossed out)
		A1		Final value of 14 Dep on M2 earned
	D ~~9^1~~ ~~6^2~~ 5^3 *G* ~~12^2~~ 8^4 *E* 8^1	A1	6	All "correct" with 2 clear routes to cost of 14 (or equivalent in tabular form)
(b)	Min cost = 14 *ABCFH* and *ABCDGH*	B1 B1 B1	3	
	Total		**9**	
4(a)	*D*	B1	1	
(b)	$(17 + 25 + 35 + 13 + 12 + 13 = 115)$	B1	1	
(c)	$ABD_{max} = 25$; $GED_{max} = 12$	B1B1	2	
(d)(i)		M1 M1 M1 A1 A1		Forward and backward flows Adjusting flows on diagram Routes and flows in chart One correct other than ABD, GED Another correct
	Route *ABD* *GED* *GFD* *GD* *AD* *AFD* *GEBD* Flow 25 12 16 13 17 15 7	A1	6	All correct
(ii)	Total = 105 Max flow 	B1 B1	2	
(iii)	Cut through *AF, AD, BD*, *DE*, *DG*, and *GF*	M1 A1	2	Through 3 saturated arcs *(fairly generous)* Correct
(e)	Reduce max flow by their *EG* changing 19 to 15 $\Rightarrow$ New max = 101	M1 A1	2	Reduce by 4 since everywhere else saturated Correct answer $\Rightarrow$ 2 marks
	Total		**16**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)	$3x+7y \le 33$ $x+2y \le 10$ $2x+7y \le 26$	M1 A1	 2	One correct inequality, or all using < All correct
(b)(i)	Compare $\frac{33}{3}, \frac{10}{1}, \frac{26}{2}$ Choose smallest positive value ⇒ pivot = 1	E1 E1	 2	
(ii)	P x y r s t Value 1 0 –1 0 4 0 40 0 0 1 1 –3 0 3 0 1 2 0 1 0 10 0 0 **3** 0 –2 1 6 next y pivot on **3** 1 0 0 0 $3\frac{1}{3}$ $\frac{1}{3}$ 42 0 0 0 1 $-2\frac{1}{3}$ $-\frac{1}{3}$ 1 0 1 0 0 $2\frac{1}{3}$ $-\frac{2}{3}$ 6 0 0 1 0 $-\frac{2}{3}$ $\frac{1}{3}$ 2	M1 A1 A1 M1 m1 A1 A1	 7	Row operation Correct one row *(other than pivot row)* All correct Row operation Correct one row (other than pivot row) All correct (condone multiples of given rows) (maximum 6 if y-pivot used first)
(iii)	No negative number in top row $P_{max} = 42$ $x = 6$ $y = 2$	E1 B1√ B1√	 3	 ft if M3 scored and optimum reached
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	Gain for Rowan +gain for Colleen in each strategy = 0	E1	1	Gain for one = loss of other
(b)	$\begin{array}{cccc\|c} & & & & \underline{\min} \\ & -3 & -4 & 1 & -4 \\ & 1 & 5 & -1 & \boxed{-1} \\ & -2 & -3 & 4 & -3 \\ \hline \text{Max} & \boxed{1} & 5 & 4 & \end{array}$	M1 A1		$\left\{\begin{array}{c}\text{minimum of rows \& max of columns} \\ \text{or} \\ \text{maximum of minima or minimax}\end{array}\right.$ All values correct (seen) or words maximin and minimax highlighted
	$1 \neq -1 \Rightarrow$ no stable solution	E1	3	
(c)	R_3 dominates R_1 $(-3,-4,1) < (-2,-3,4)$ so never play R_1	E1	1	
(d)(i)	R chooses R_2 with prob p $\Rightarrow$ choose R_3 with prob $1-p$ $\Rightarrow$ expected gain when C plays $C_1: p-2(1-p)=3p-2$ $C_2: 5p-3(1-p)=8p-3$ $C_3: -p+4(1-p)=4-5p$	M1 A1		Attempt at one expression All correct unsimplified
	Plot expected gains for $0 \le p \le 1$  	M1 A1		Condone mirror image
	Choosing their "highest" point C_1 & C_3 intersect $\Rightarrow 3p-2=4-5p$ $\Rightarrow p=\frac{3}{4}$ $\Rightarrow$ play R_2 with prob $\frac{3}{4}$ and R_3 with prob $\frac{1}{4}$	M1 A1 E1√	7	Any 2 lines Statement of strategy
(ii)	Value of game is $3 \times \frac{3}{4} - 2 = \frac{1}{4}$	B1	1	CSO or equivalent, eg 0.25
	Total		**13**	
	TOTAL		**75**	

Version : 1.0 0107

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2007 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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX
Dr Michael Cresswell Director General

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**.

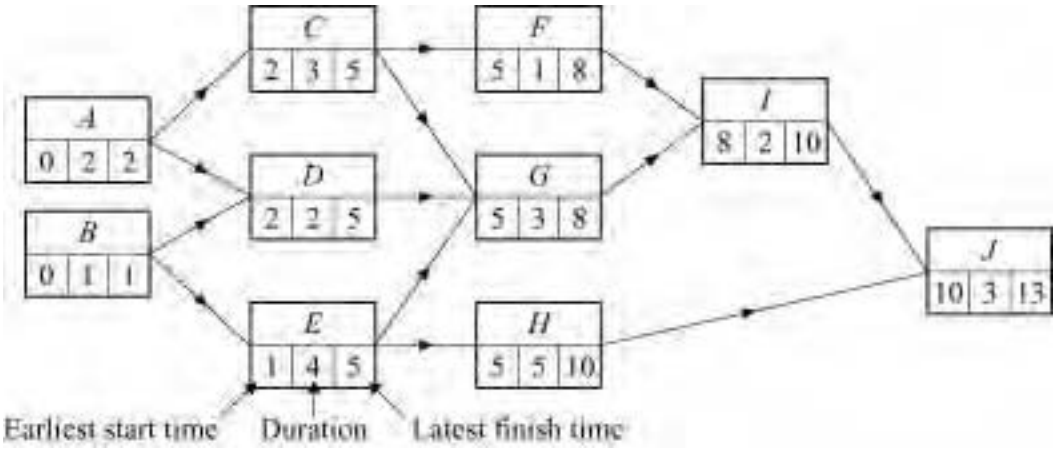
Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

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**.

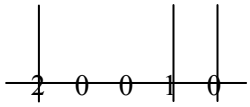
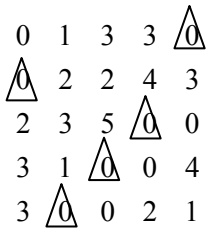
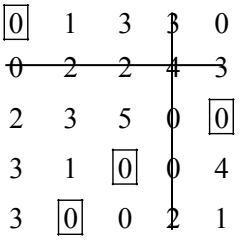
Otherwise we require evidence of a correct method for any marks to be awarded.

Jan 07

MD02

Q	Solution	Marks	Total	Comments
1(a)	Network attempted	M1		SCA
	up to 2 slips (boxes or arrows)	A1		
	correct network	A1	3	
				
(b)	Forward pass	M1		
	correct	A1	2	
(c)	Backward pass	M1		
	correct	A1	2	
(d)	Minimum completion time: 13 weeks	B1		
	Critical paths: *ACGIJ*	B1		
	BEGIJ	B1		
	BEHJ	B1	4	
	Total		**11**	

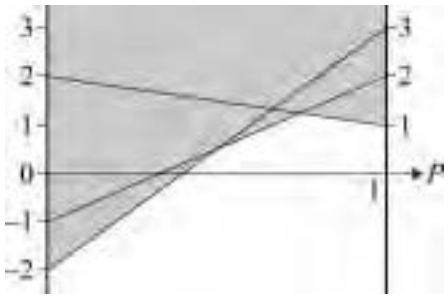
MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	Hungarian algorithm **minimises**	E1		
	$15 - x$ gives measure of criteria NOT met which need minimising in order to maximise scores	E1	2	idea of high becoming low, etc.
(b)	2 4 6 5 2 0 3 3 4 3 3 5 7 1 1 4 3 2 1 5 3 1 1 2 1	B1		array giving $15 - x$
	0 2 4 3 0 0 3 3 4 3 2 4 6 0 0 3 2 1 0 4 2 0 0 1 0	M1 A1		reduce rows (or columns then rows) reduced array correct
	Zeros can be covered with only **4 lines** so adjustment needed	E1		 augmented array
	Reduction by subtracting 1 from each uncovered element and adding 1 to each element at intersection of two lines	M1 A1		
	Matching on particular zeros Alex ↔ (5) Don ↔ (3) Bill ↔ (1) Ed ↔ (2) Cath ↔ (4)	M1 A1	8	
	If adjustment **not** done correctly and matching made, award B1 for 3 correct and B1 for rest correct			Award last 2 marks in whichever way benefits candidate most
(c)	Deleting row 2 and column 4 either in final matrix or reworking Final solution: A ↔ (1) C ↔ (5) D ↔ (3) E ↔ (2)	M1 A1 A1	3	
	If no method award B2 if matching is all correct			
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	P x y z s t Value 1 -5 -8 -7 0 0 0 0 3 2 1 1 0 12 0 2 (4) 5 0 1 16	M1 A2	3	SCA -1 EE
(b)(i)	$\frac{12}{2}=6$; $\frac{16}{4}=4$ and $4<6$	E1	1	
(ii)	1 -1 0 3 0 2 32 0 (2) 0 $-1\frac{1}{2}$ 1 $-\frac{1}{2}$ 4 0 $\frac{1}{2}$ 1 $1\frac{1}{4}$ 0 $\frac{1}{4}$ 4	M1 A1 A1		using 4 as pivot and possibly dividing third row by 4 top row correct second row correct; may have 0 2 4 5 0 1 16
	choice of pivot from x-column	M1		pivot = (2) identified and used
	1 0 0 $2\frac{1}{4}$ $\frac{1}{2}$ $1\frac{3}{4}$ 34 0 1 0 $-\frac{3}{4}$ $\frac{1}{2}$ $-\frac{1}{4}$ 2 0 0 1 $1\frac{5}{8}$ $-\frac{1}{4}$ $\frac{3}{8}$ 3	m1 A1	6	row operations correct or scaled up 0 0 4 $6\frac{1}{2}$ -1 $1\frac{1}{2}$ 12
(iii)	Max $P=34$ $x=2,\ y=3,\ z=0$	B1√ B1	2	all correct
(iv)	Yes - no negative values in first row	E1√	1	no – if negatives in top row
	Total		**13**	

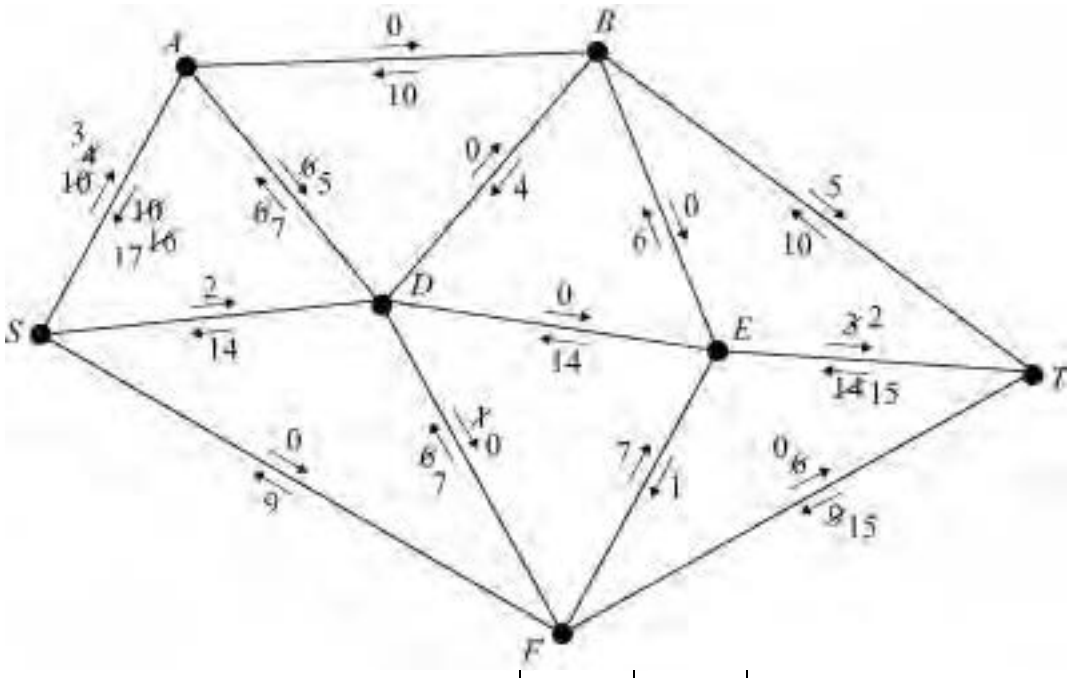
MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	Row min -4 -2 -1 Col max 5 -1 3	M1 A1		Attempt at row minimum and column maximum all figures correct
	min (col max) = max (row min) $\Rightarrow$ stable solution	E1	3	
(ii)	Ros plays III and Col plays Y value of game = -1	B1 B1	2	
(b)(i)	Ros plays R_1 with probability p and R_2 with probability $1-p$ Expected gains when Col plays: $C_1 : 3p-2(1-p)=5p-2$ $C_2 : 2p-(1-p)=3p-1$ $C_3 : p+2(1-p)=2-p$	 M1 A1		 attempt at least 2 correct unsimplified
	Plot expected gains against p for $0 \le p \le 1$	M1		
		A1		correct (must see 0 or 1 on P axis, or implied by their numbers) A0 if not possible to see highest point of region being correct
	Choose highest point of region below lines $\Rightarrow 3p-1=2-p$	M1		must be this pair of lines or their highest point
	leading to $p=\frac{3}{4}$	A1		
	Therefore Ros plays R_1 with prob $\frac{3}{4}$ and plays R_2 with prob $\frac{1}{4}$	B1√	7	ft their p from any lines
(ii)	Value of game $= 3\times\frac{3}{4}-1$ or $\left(2-\frac{3}{4}\right) = 1\frac{1}{4}$	B1	1	
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)	*SAET* has least day's sunshine of 5 hours whereas for *SACT* least value is only 4 hours	M1 A1	2	Reasonable understanding Mention of 4 and 5 hours and clear idea that minimum is larger in *SAET*
(b)	Stage / Initial State / Action / Value	M1		General idea of stage and state
	1 / *C* / *CT* / 7* *D* / *DT* / 9* *E* / *ET* / 5*	A1		First stage correct (may be reversed)
	2 / *A* / *AC* / min (4, 7) = 4 *AD* / min (4, 9) = 4 *AE* / min (5, 5) = 5*	M1 m1		Finding least value from 2 legs Finding max of minima (star values)
	B / *BC* / min (6, 7) = 6* *BD* / min (5, 9) = 5 *BE* / min (7, 5) = 5	A1		All values in second stage correct
	3 / *S* / *SA* / min (9, 5) = 5 *SB* / min (8, 6) = 6*	A1		All values in third stage correct
		A1		All values correct (inc max of min all correct) **and** minimum comparison clearly shown at each stage, particularly (9, 5) and (8, 6) in third stage
	Maximin route is *SBCT*	B1	8	Award B1 even without dynamic programming
	Total		**10**	

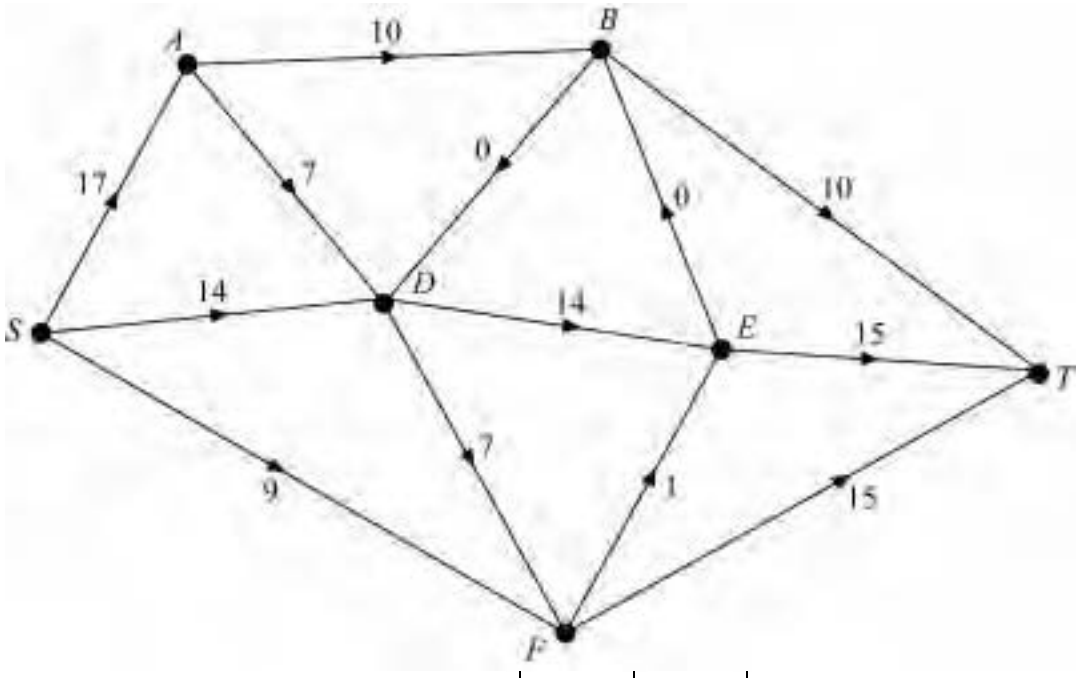
MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)(i)	15 + 0 + 14 + 7 + 9 = 45	B1	1	
(ii)	Maximum flow ≤ 45	M1		≤ their value or < 45
		A1	2	correct
(b)	*SABT* flow 10 *SDET* flow 14	B1		one correct
	SFT flow 9 (may appear in table below)	B1	2	two more correct
(c)(i)				
	Additional route	M1		
	with correct flow	A1		
	one more correct route and flow	A1		
	table complete	A1		correct total flow of 40
	correct use of potential and used flows	M1		on network (may use double edges)
	values correctly updated	A1	6	**strict**

Route	Flow
SABT	10
SDET	14
SFT	9
SADFT	6
SADFET	1

several possibilities

MD02 (cont)

Q	Solution	Marks	Total	Comments
6 (cont) **(c)(ii)**				
	Maximum flow = 40 Network showing flow of 40	B1 B1	2	
(iii)	Cut through saturated arcs *AB*, *BD*, *DE*, *DF*, *SF* Minimum cut shown to be 40 with statement linking to maximum flow	M1 A1	2	
	Total		**15**	
	TOTAL		**75**	

Version 1.0 06.07

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2007 examination - June 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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX
Dr Michael Cresswell Director General

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**.

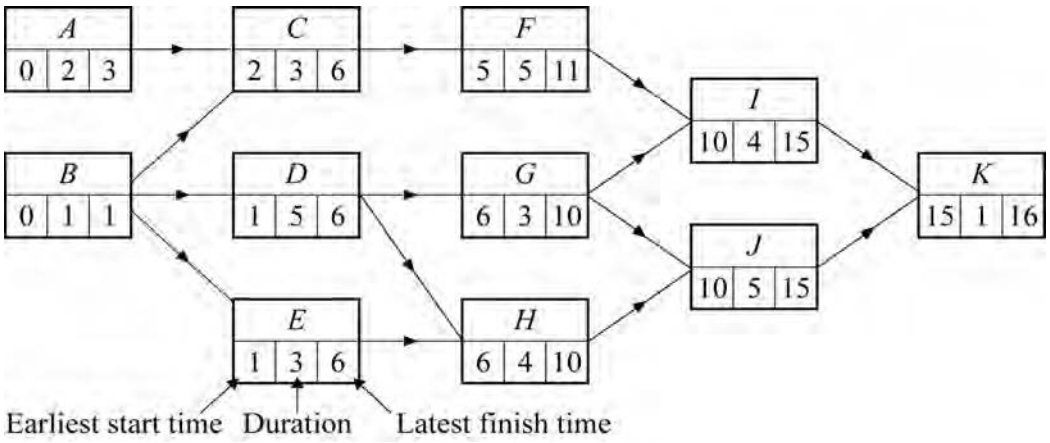
Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

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.

June 07

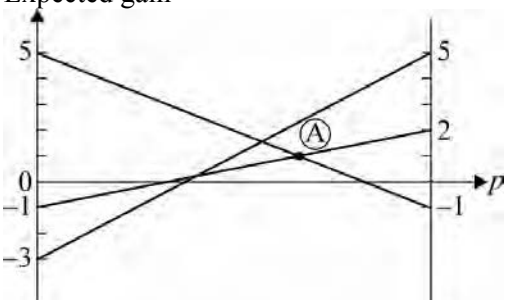
MD02

Q	Solution	Marks	Total	Comments
1(a)				
	Activity / **Immediate Predecessors** *A* : - *B* : - *C* : *A, B* *D* : *B* *E* : *B* *F* : *C* *G* : *D* *H* : *D, E* *I* : *F, G* *J* : *G, H* *K* : *I, J*	M1 A1	2	Up to 2 slips All correct
(b)		M1 A1 M1 A1	4	Start times – up to 1 slip with FT All correct Finish times – up to 1 slip; FT 'their 16' All correct; CSO
(c)	Critical path *B D H J K* Minimum time 16 days	B1 B1	2	
(d)	Greatest float at *E* Value = 2	B1√ B1√	2	
	Total		**10**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	10 11 8 12 5 11 5 11 6 7 12 8 7 11 4 10 9 14 10 6 9 9 7 8 9			
	5 6 3 7 0 6 0 6 1 2 8 4 3 7 0 4 3 8 4 0 2 2 0 1 2	M1 A1		Row reduction up to 2 slips Correct
	Printed answer	A1	3	Columns AG
(b)	3 6 3 6 ~~0~~ ~~4 0 6 0 2~~ 6 4 3 6 ~~0~~ 2 3 8 3 ~~0~~ ~~0 2 0 0 2~~	B1		Covering zeros with 3 lines
	1 4 1 4 0 4 0 6 0 4 4 2 1 4 0 0 1 6 1 0 0 2 0 0 4	M1 A1		Subtract 2 from uncovered and add 2 to double covered Table correct
	Can now be covered with 4 lines, so reduce again	M1		Subtract 1 from uncovered; Add 1 to double covered
	1 3 0 3 0 or 0 3 0 3 0 5 0 6 0 5 4 0 6 0 5 4 1 0 3 0 3 1 0 3 0 0 0 5 0 0 0 1 6 1 1 1 2 0 0 5 0 2 0 0 5	A1	5	
(c)	Matching $A-4, B-2, D-5$ And either C – 1, $E-3$ or $C-3, E-1$	B1 B1 B1	3	
(d)	$(10+5+8)+(8+4)=$£35	B1	1	
	Total		**12**	

MD02 (cont)

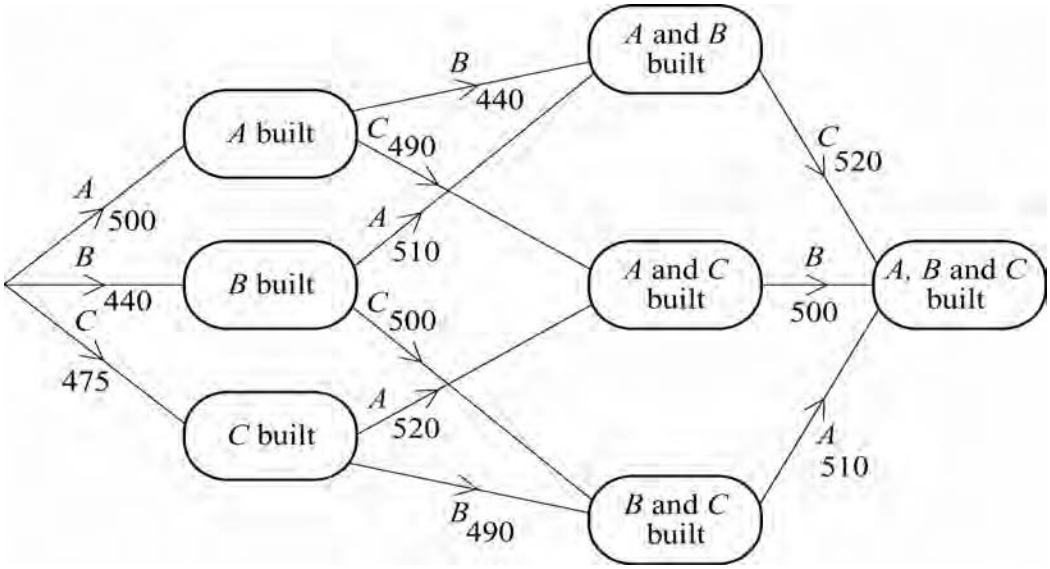
Q	Solution	Marks	Total	Comments
3(a)(i)	Min $R_1(5, 2, -1) = -1$ Min $R_2(-3, -1, 5) = -3$ Min $R_3(4, 1, -2) = -2$ Max min = -1 $\Rightarrow$ Play safe strategy R_1	E1 B1	2	
(ii)	Max $C_1 = 5$; max $C_2 = 2$; max $C_3 = 5$ Min $(5, 2, 5) = 2$ $2 \neq -1 \Rightarrow$ no stable solution	M1 A1	2	
(b)	$R_3(4, 1, -2) < R_1(5, 2, -1)$	E1	1	
(c)(i)	C_1 played, expected gain for Rose: $5p + -3(1-p)$ $= 8p - 3$ $C_2 : 2p - (1-p) = 3p - 1$ $C_3 : -p + 5(1-p) = 5 - 6p$	M1 A1 A1	3	Any correct expected gain unsimplified One correct simplified All correct simplified
(ii)	Expected gain  	M1 A1	2	Plotting at least 2 lines All correct with values at $p = 0$ and $p = 1$ indicated
(iii)	Choosing A – highest point in feasible region $\Rightarrow 3p - 1 = 5 - 6p$ $9p = 6$ $\Rightarrow p = \frac{2}{3}$ $\Rightarrow$ Rose plays R_1 $\frac{2}{3}$ of time and R_2 $\frac{1}{3}$ of time	M1 A1 E1√	3	Solving this equation CSO
(iv)	Value of game $= 3 \times \frac{2}{3} - 1 = 1$	B1	1	Or $5 - 4 = 1$
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)	$x + 2y \le 36$ $x + y \le 20$ $4x + y \le 39$	M1 A1	 2	One correct, or all inequalities with < All correct
(b)(i)	Choosing 2 as pivot	M1		And perhaps dividing second row by 2
	P x y s t u value 1 $-\frac{1}{2}$ 0 $2\frac{1}{2}$ 0 0 90	m1		Row operations
	0 $\frac{1}{2}$ 1 $\frac{1}{2}$ 0 0 18 0 $\left(\frac{1}{2}\right)$ 0 $-\frac{1}{2}$ 1 0 2	A1		One row correct
	0 $3\frac{1}{2}$ 0 $-\frac{1}{2}$ 0 1 21	A1	4	All rows correct (condone multiples of rows)
(ii)	Negative value in top row $\Rightarrow$ optimum not yet reached	E1	1	
(c)(i)	New pivot $(x-$column, 3rd row$)$	M1		And perhaps multiplying by 2
	P x y s t u value 1 0 0 2 1 0 92	m1		Row operations
	0 0 1 1 –1 0 16 0 1 0 –1 2 0 4	A1		One row correct
	0 0 0 3 –7 1 7	A1	4	All rows correct
(ii)	Optimum value reached	E1		(Or not? – if their tableau wrong)
	$P = 92, x = 4, y = 16$ $s = 0, t = 0, u = 7$	B1√ B1	 3	FT 3 values CSO (final tableau must be correct)
	Total		**14**	

MD02 (cont)

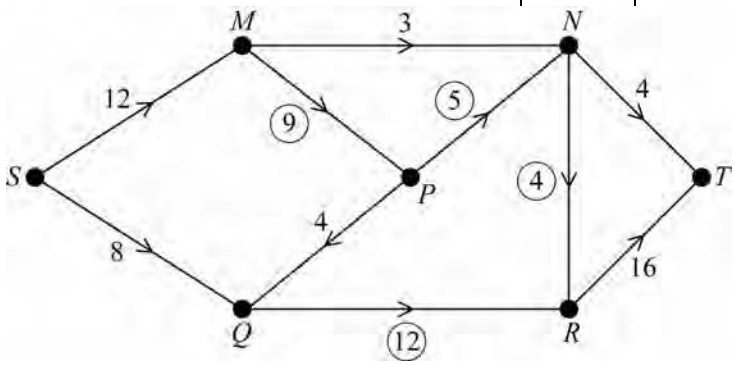
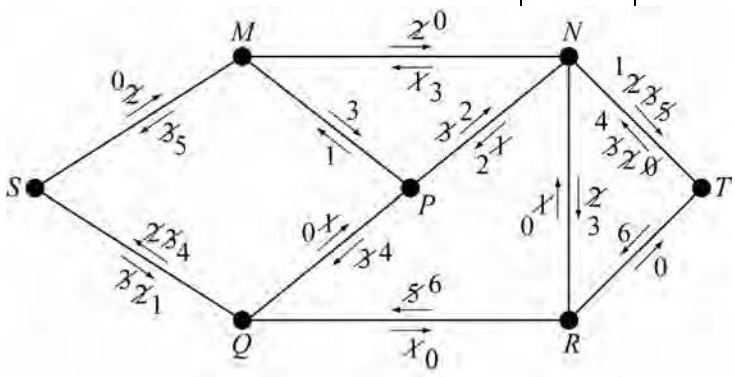
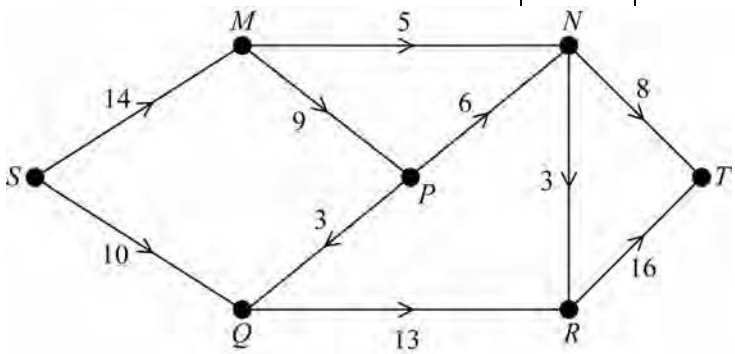
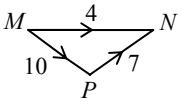
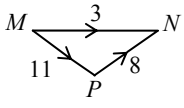
Q	Solution	Marks	Total	Comments
5(a)	(May use correct network instead of table but **must** work backwards through network)			



Month	Already Built	Machine Built	Cost (£)	Total Cost (* = min)
3	*A* and *B*	*C*	520	520*
	A and *C*	*B*	500	500*
	B and C	A	510	510*
2	*A*	*B*	440	440 + 520 = 960*
		C	500	490 + 500 = 990
	B	*A*	510	510 + 520 = 1030
		C	500	500 + 510= 1010*
	C	*A*	520	520 + 500 = 1020
		B	490	490 + 510 = 1000*
1	-	*A*	500	500 + 960 = 1460
	-	*B*	440	440 + 1010= 1450*
	-	*C*	475	475 + 1000= 1475

		B1	Month 3 costs correct
		M1	6 values in month 2 (4 correct)
		A1	All correct
		M1	3 values using minimum from month 2
		A1	All correct and asterisks correct
	Order is *BCA*	B1	6
(b)	Choosing other values at stage 2	B1√	990*, 1030*, 1020*
	New totals at stage 1	M1 A1	500 + 990 = 1490 440 + 1030 = 1470 475 + 1020 = 1495*
	Maximum profit *CAB*	B1	4
	Total		**10**

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)(i)	$5 + 8 + 16 - 3 = 26$	B1	1	
(ii)	Max flow ≤ 26	E1√	1	
(b)		B1 *MP* – 9 B1 *PN* – 5 B1 *NR* – 4 B1 *QR* – 12	4	
(c)(i)		M1 initial flow – forward and backward 6 pairs correct A1 correct *OM* 2 & 3; *MN* 2 & 1 *NT* 5 & 0; *MP* 3 & 1 *SQ* 3 & 2; *PQ* 3 & 1 *PN* 3 & 1; *QR* 1 & 5 *NR* 2 & 1; *RT* 0 & 6	2	
(ii)	Adjusting flows on network **Path** / **Flow** *SMNT* 2 *SQPNT* 1 *SQRNT* 1	M1A1 B1 B1 B1	5	First correct path and flow Second correct Rest
(iii)		M1 6 flows correct A1 all correct Or  or 	2	
	Total		**15**	
	TOTAL		**75**	

Version 1.0: 01.08

ASSESSMENT and QUALIFICATIONS ALLIANCE

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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX
Dr Michael Cresswell Director General

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**.

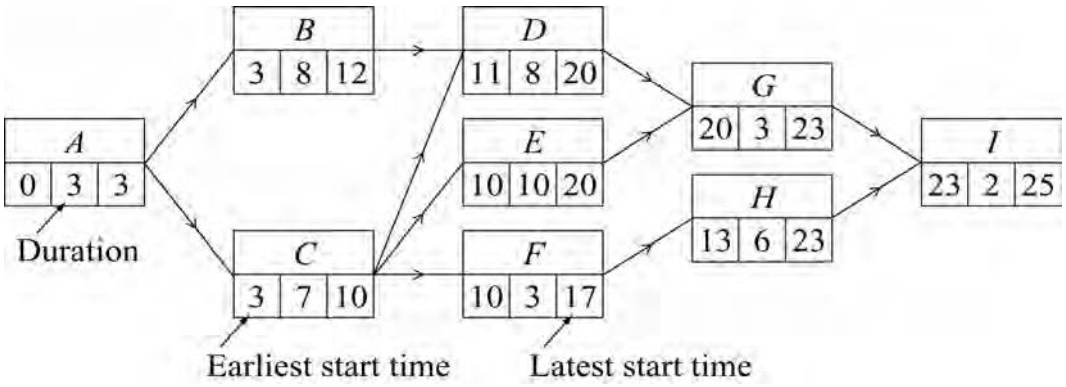
Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

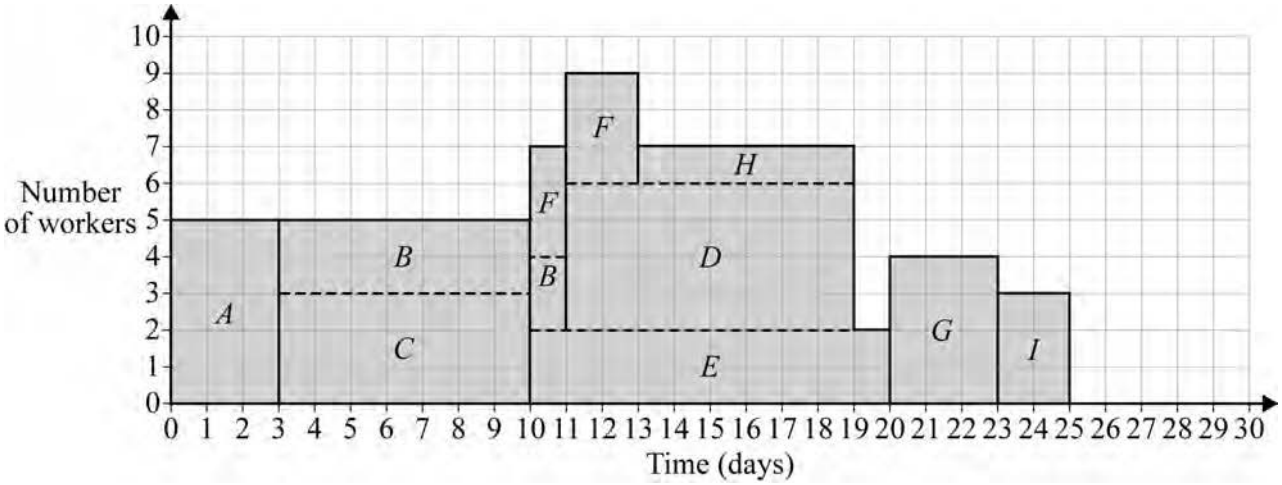
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MD02

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





MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)				
		B1	1	Extra row of equal non-zero values (expect 15, 15, …)
(b)				
		M1		Attempt to reduce columns
		A1		Correct
				Final row may be different
		A1		Reduce rows correct
		B1		Zeros can be covered with 4 lines (shown)
		M1		Adjustment reducing uncovered elements by 1 and increasing double uncovered by 1
		A1		Correct
	Matching E3, B4, C2, D1	B1		
	Total time 44 min	B1	8	
(c)	No, time cannot be improved ** became 0 from 2nd tableau onwards B must take task 4 ⇒ D must …	B1 E1	2	Or other correct reasoning
	Total		**11**	

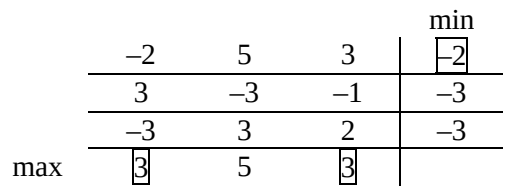
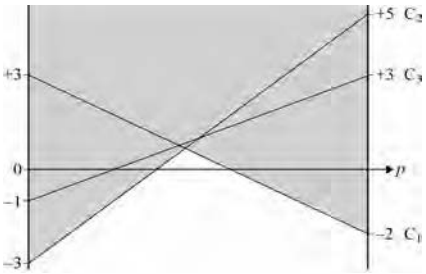
	Ash	Bob	Col	Dan	Emma
Task 1	14	10	12	12	14
Task 2	11	13	10	12	12
Task 3	13	11	12	**	12
Task 4	13	10	12	13	15
	15	15	15	15	15

	Ash	Bob	Col	Dan	Emma
Task 1	3	0	2	0	2
Task 2	0	3	0	0	0
Task 3	2	1	2	**	0
Task 4	2	0	2	1	3
	4	5	5	3	3

	Ash	Bob	Col	Dan	Emma
Task 1	3	0	2	0	2
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

	Ash	Bob	Col	Dan	Emma
Task 1	2	0	1	0	2
Task 2	0	4	0	1	1
Task 3	1	1	1	**	0
Task 4	1	0	1	1	3
	0	2	1	0	0

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	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)	 	B1 M1		min of rows and max of columns All values correct (seen) maximin = -2 minimax = 3 either correct
	$-2 \neq 3$ $\Rightarrow$ no stable solution	E1	3	
(c)	R_3 dominated by R_1 $(-3, 3, 2) < (-2, 5, 3)$ so never play R_3	E1	1	
(d)(i)	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 A1		Attempt at one expression All correct unsimplified
	 	M1 A1		Plotting expected gain for $0 \leq p \leq 1$ Correct with values at $p = 0$ and $p = 1$ clear
	$3 - 5p = 8p - 3$ $\Rightarrow p = \frac{6}{13}$ Play R_1 with probability $\frac{6}{13}$ and R_2 with probability $\frac{7}{13}$	M1 A1 E1√	7	Choosing C_1 and C_2 intersection or their highest point FT their p (statement needed)
(ii)	Value of game $= 3 - \frac{30}{13}$ $= \frac{9}{13}$	B1	1	Or $\frac{48}{13} - 3$ $= \frac{9}{13}$
	Total		**13**	

MD02 (cont)

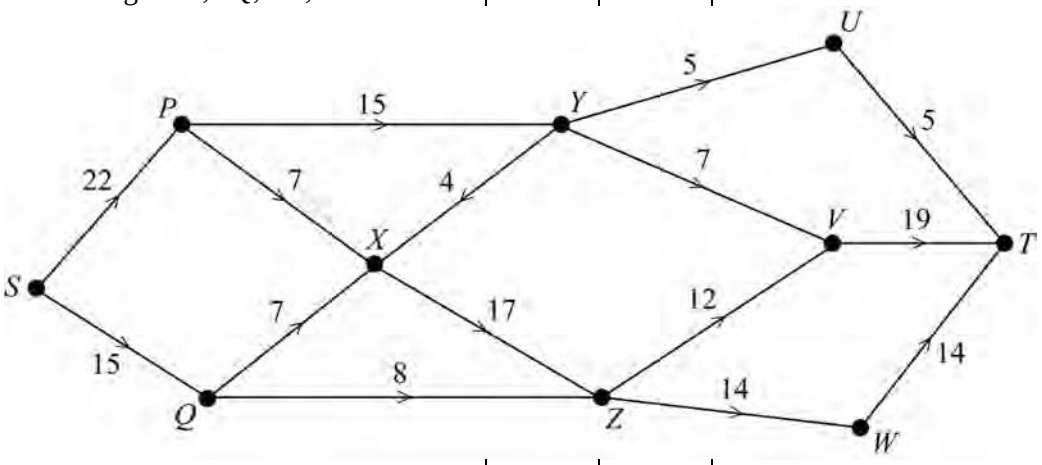
Q	Solution	Marks	Total	Comments
4(a)	$x + z \le 9$ $2x + y + 4z \le 40$ $4x + 2y + 3z \le 33$	M1 A1	 2	One correct inequality or all using < All correct
(b)(i)	Pivot is **1** in z-column	M1		May be implied by use
	P | x | y | z | s | t | u | value 1 | 3 | –3 | 0 | 5 | 0 | 0 | 45 0 | 1 | 0 | **1** | 1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

MD02 (cont)

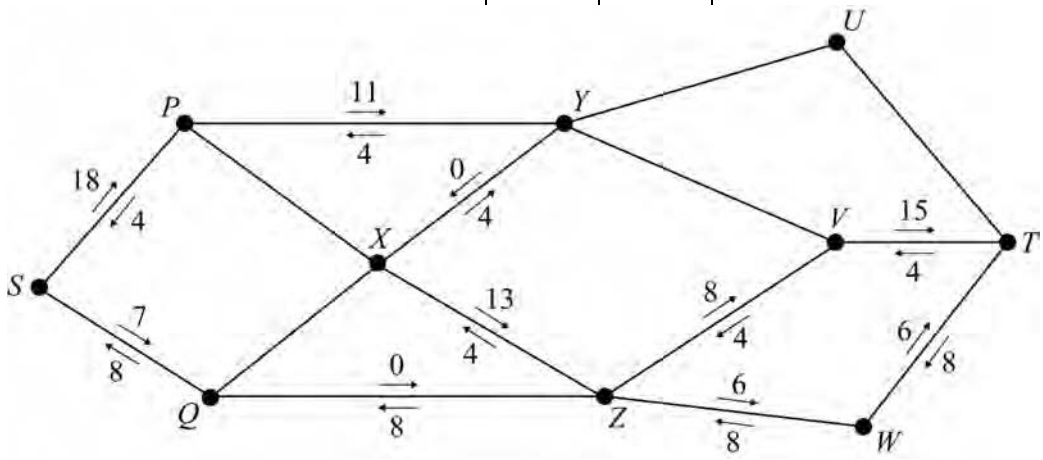
Q	Stage	State	From	Value	Marks	Total	Comments
5(a)	Stage	State	From	Value			
	1	*H*	*T*	5 *			
		I	*T*	6 *			
	2	*F*	*H*	–2 + 5 = 3 *	B1		Stage 2 values correct
			T	4			
			I	–2 + 6 = 4			
		G	*I*	5 + 6 = 11 *			
	3	*C*	*H*	4 + 5 = 9	M1		Stage 3 (6 values)
			F	5 + 3 = 8 *			
			G	2 + 11 = 13			M0 for complete enumeration
		D	*G*	–1+11 = 10*			
		E	*F*	5 + 3 = 8 *	A1		Correct
			G	3 +11 = 14			
	4	*A*	*C*	2 + 8 = 10	M1		Stage 4 (4 values) and using minimum values from previous stage
			D	–1+10 = 9 *			
		B	*D*	–2 +10 = 8	A1		Stage 4 correct
			E	–3 + 8 = 5 *			
	5	*S*	*A*	1 + 9 = 10 *			
			B	5 + 5 = 10 *	A1	6	Stage 5 correct CSO
(b)	Minimum cost 10				B1		
	Routes *SBEFHT*				B1		First route correct
	SADGIT				B1	3	Second correct (no others)
				Total		**9**	

MD02 (cont)

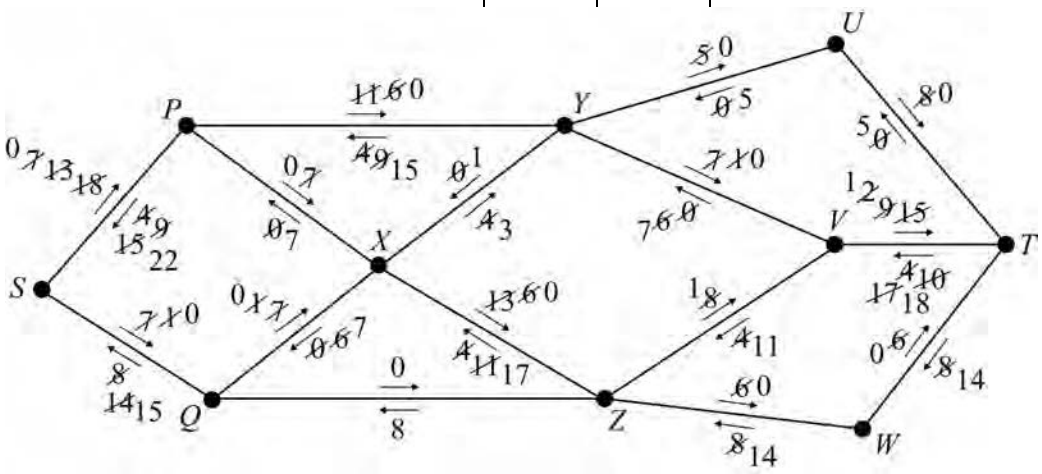
Q	Solution	Marks	Total	Comments
6(a)	Correct position of *S* and *T* Values on edges *SP*, *SQ*, *UT*, *VT* and *WT*	M1 A1	2	



(b)(i)	Cut *C* has value 40	B1	1	15 + 0 + 17 + 8
(ii)	Max flow ≤ 40	E1	1	
(c)	**Route** / **Flow** *SQZWT* / 8 *SPYXZVT* / 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)				(Many different possibilities)
	Route / **Flow** *SQZWT* 8 *SPYXZVT* 4 *SPYUT* 5 *SPYVT* 6 *SPXZVT* 7 *SQXZWT* 6 *SQXYVT* 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
				Other possibility for ZV, VT, ZW and WT
(e)	Flow from *Y* to *X* is 3	B1	1	
	Total		**13**	
	TOTAL		**75**	

Version 1.0: 0608

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2008 examination – June 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.

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.

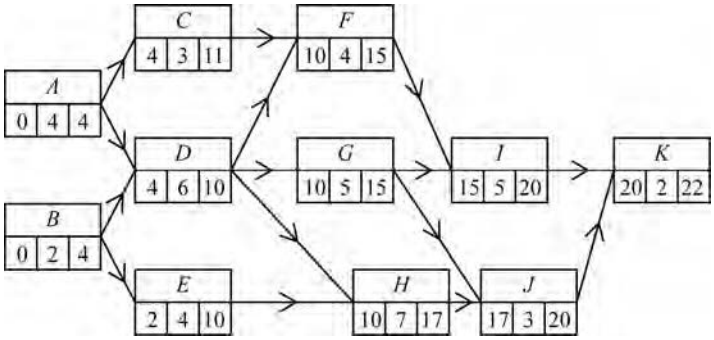
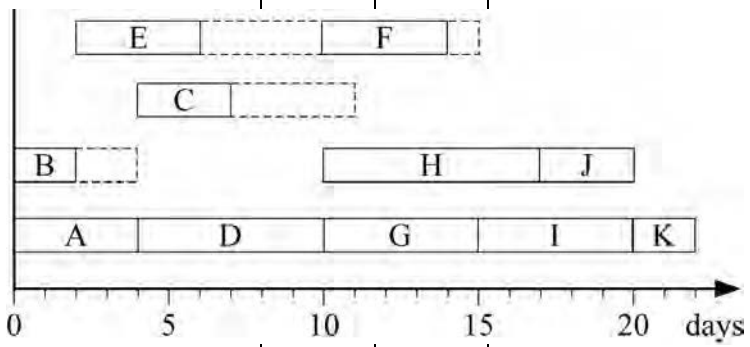
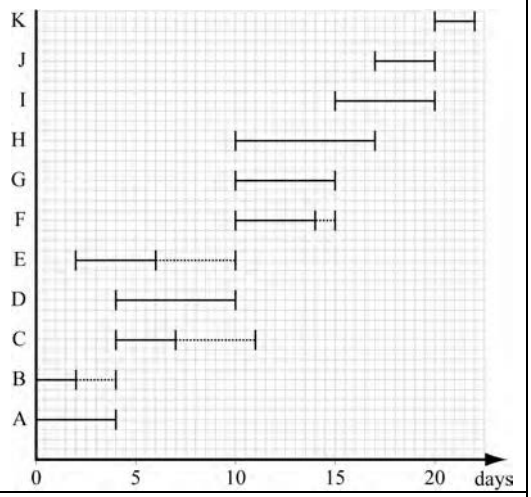
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

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

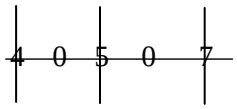
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

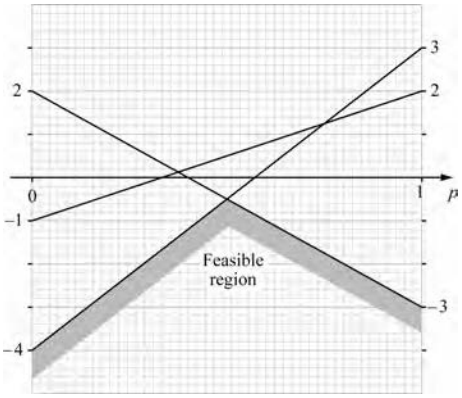
MD02

Q	Solution	Marks	Total	Comments
1				
(a)	Earliest start times	M1		up to 2 errors ft
	All correct	A1		
	Latest finish times	M1		up to 2 errors ft from *K*
	Correct	A1	4	
(b)	Critical paths *A D G I K*	B1		
	A D H J K	B1		withhold if extra path such as *A D G J K* given
	Minimum time for completion = 22 days	B1	3	Must be stated – not just a value in box on insert
(c)				
	A, D, G, H, I, J, K correct	B1		
	B, C, E, F	B1		2 correct with slack /float or 4 correct & no slack
		B1	3	all correct with slack/float; withhold if slack not shown dotted etc
(d)	*F* starts after 12 days at earliest or *F* starts 2 days later	E1		
	I is now unable to start until after 16 days or *I* starts 1 day later			
	Minimum completion time now 23 days – one extra day etc	B1	2	
	Total		**12**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	Hungarian algorithm minimises	E1		
	$20 - x$ indicates how many points NOT scored	E1	2	idea of high becoming low
(b)	3 4 1 3 0 0 7 5 4 2 4 3 5 2 7 7 6 2 5 3 5 4 0 4 5	B1		
	3 1 1 1 0 0 4 5 2 2 4 0 5 0 7 7 3 2 3 3 5 1 0 2 5	M1		column reduction, allow one slip from $20 - x$ table
	3 1 1 1 0 0 4 5 2 2 4 0 5 0 7 5 1 0 1 1 5 1 0 2 5	A1	3	then row reduction AG but previous table must be correct
(c)	Lines drawn	B1		
	Reduce all uncovered by 1 and add 1 to all doubly covered	M1		
	3 0 1 0 0 0 3 5 1 2 5 0 6 0 8 5 0 0 0 1 5 0 0 1 5	A1	3	allow M1A1 if lines not as above
(d)	Choosing zeros in first and last columns Alice – Game 2; Ede – Game 1	B1		Allow if only circles around these entries with no matching listed
	Possible options B – 3 ; D – 4 ; C – 5 B – 4 ; D – 3 ; C – 5 B – 5 ; C – 4 ; D – 3	B1 B1 B1	4	
(e)	Maximum score = 92	B1	1	
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)(i)	Roseanne plays R_1 with prob p Expected value when Collette plays $C_1 : -3p + 2(1-p) = 2 - 5p$			
	$C_2 : 2p - (1-p) = 3p - 1$	M1		One correct unsimplified
	$C_3 : 3p - 4(1-p) = 7p - 4$	A1		All correct unsimplified
		M1		drawing 'their' lines (2 'correct' ft)
		A1		correct with values clear at $p = 0$ and $p = 1$
	Solving $2 - 5p = 7p - 4$ $6 = 12p$ $\Rightarrow p = \frac{1}{2}$	M1 A1		their highest point } SC B1 if $p = \frac{1}{2}$ found from graph
	Strategy is to play R_1 for 50% of time	E1√	7	
(ii)	Value $= 2 - 5\left(\frac{1}{2}\right)$ or $7\left(\frac{1}{2}\right) - 4 = -\frac{1}{2}$	B1	1	AG CSO $p = \frac{1}{2}$ and both expressions correct
(b)(i)	Let Collette play C_1 with prob p and C_2 with prob q $\Rightarrow C_3$ with prob $1 - p - q$	B1	1	
(ii)	$-3p + 2q + 3(1-p-q) = -\frac{1}{2}$ $2p - q - 4(1-p-q) = -\frac{1}{2}$	M1		Either equation LHS correct Condone $(1-p+q)$ used
	$\Rightarrow 6p + q = 3\frac{1}{2}$ $6p + 3q = 3\frac{1}{2}$	A1		Either equation correct and simplified p & q coefficients
	$\Rightarrow p = \frac{7}{12}$ $q = 0$	A1		CSO
	$\Rightarrow$ Collette plays C_1 with prob $\frac{7}{12}$, (never plays C_2), and plays C_3 with prob $\frac{5}{12}$	E1	4	Must have statement with C_1 & C_3 **correct only**
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	4 is chosen as pivot $\frac{20}{4} = 5 < \frac{14}{2} = 7$ and $5 < \frac{8}{1} = 8$	B1 E1	2	Must have 3 values possibly unsimplified plus comment about smallest (positive) quotient
(ii)	P x y z s t u v value 1 0 0 0 5 6 0 3 97 0 1 0 0 1 8 0 2 56 0 0 1 0 0 $\frac{3}{4}$ 0 $\frac{1}{4}$ 5 0 0 0 0 –3 $\frac{1}{2}$ 1 $-\frac{1}{2}$ 4 0 0 0 1 2 $4\frac{1}{4}$ 0 $-\frac{1}{4}$ 3	B1 B1 B1 B1	4	may be left as $\{0\ 0\ 4\ 0\ 0\ 3\ 0\ 1\ 20\}$ or multiples of these rows SC MI for row operations if wrong pivot used SC B1+B1 max ft if pivot row incorrect after ÷ 4
(b)	Optimum since no negative values in first row	E1	1	Must have attempted row operations
(c)	Maximum $P = 97$ $x = 56,\ y = 5,\ z = 3$	B1√ B1√	2	
(d)	$s = 0,\ t = 0,\ v = 0,\ u = 4$ $\Rightarrow$ only 1 of original inequalities has some slack	B1√ E1√	2	Ft if >1 non-zero slack variables
	Total		**11**	

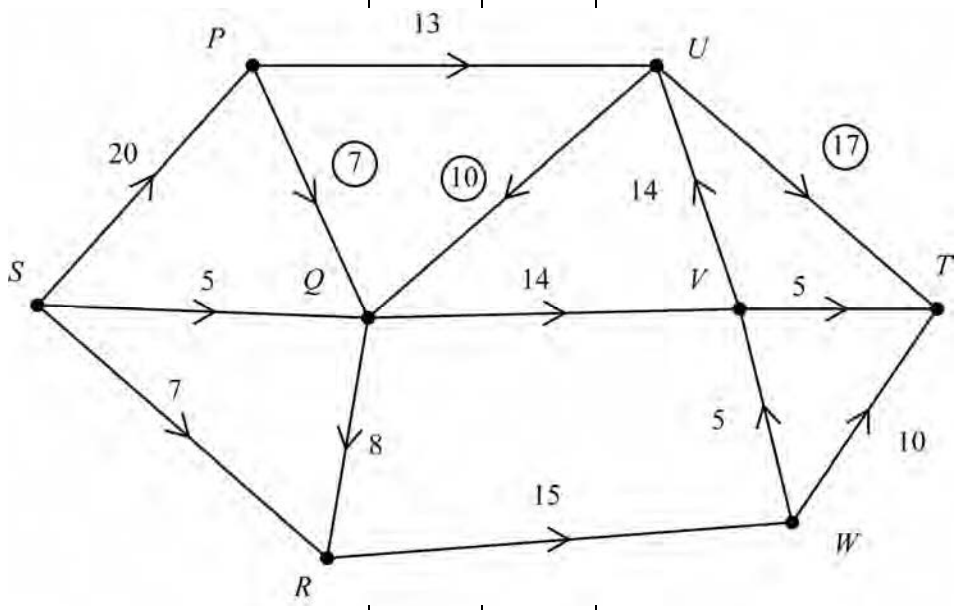
MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)	Overhead cost = £300	M1		considering overhead and storage of 2 cabinets
	Storing 2 cabinets $= 2 \times £50$ $\Rightarrow$ Total cost = £400	A1	2	
(b)				
	March values £700 £750	B1 B1		
	Choosing minima for March (at least one), their 650 or 700 seen in February values	M1		
	February state 0 $300 + 0 + 650 = 950$	B1		
	February state 1 $300 + 50 + 650 = 1000$ $300 + 50 + 700 = 1050$ February state 2 $300 + 100 + 650 = 1050$ $300 + 100 + 700 = 1100$	A1		
	January values 1250 and 1300	B1		
	Choosing least value of January and working backwards through table to select actions A_1, A_2 and A_3	M1		
	Schedule correct	A1	8	SC: B1 for schedule without DP Jan: 3, Feb: 4, Mar: 4, Apr: 2 Should get 3 or 4 when table completed
(c)	Profit excluding answer to (b) $13 \times £(2000 - 300)$ $- 4 \times £2000$ $= £14100$	M1 A1		Generous
	Total profit over 4 months is £14100 – £1250 = £12850	A1√	3	Ft their £1250
	Total		**13**	

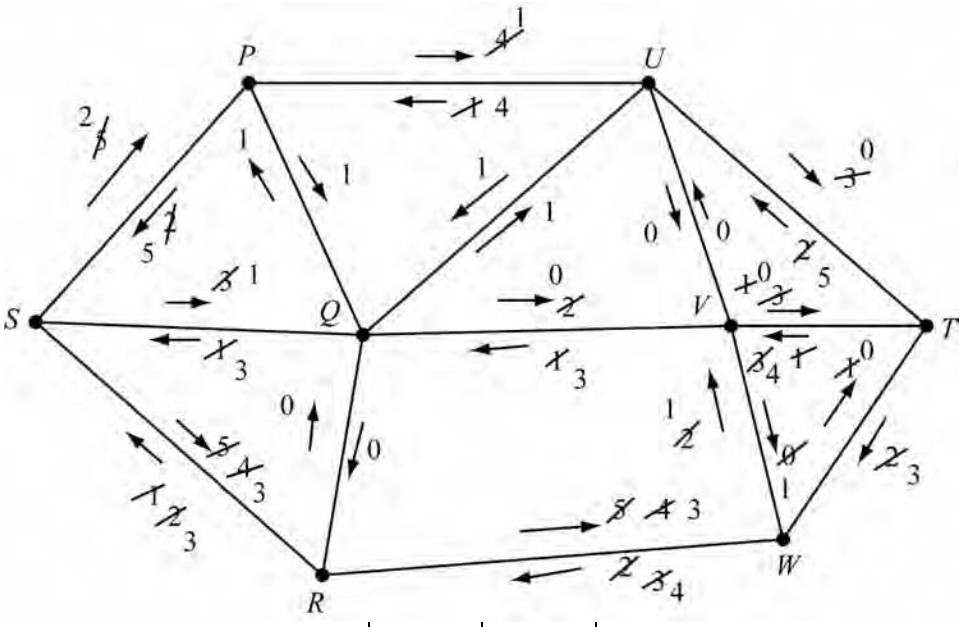
Month	State	Value	
Apr	0	300 + 0 = 300	A_3
	1	300 + 50 = 350	
Mar	1	300 + 50 + 300 = 650	A_2
	2	300 + 100 + 300 = 700	Min
		300 + 100 + 350 = 750	
Feb	0	300 + 0 + 650 = 950	A_1
	1	300 + 50 + 650 = 1000	Min
		300 + 50 + 700 = 1050	
	2	300 + 100 + 650 = 1050	
		300 + 100 + 700 = 1100	
Jan	0	300 + 0 + 950 = 1250	Min
		300 + 0 + 1000 = 1300	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)(i)	$17 - 9 + 16 + 20 = 44$	B1	1	
(ii)	Max flow ≤ 44	B1√	1	
(b)		B1		7
		B1		10
		B1	3	17



(c)(i)	Initial forward and backward flows	M1		5 pairs correct
	Correct	A1	2	

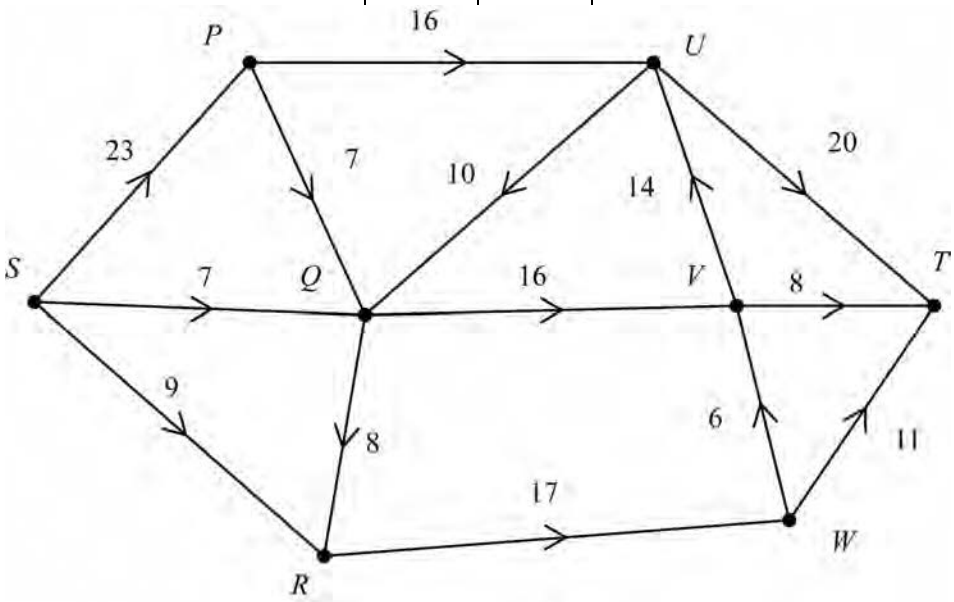


(ii)

Path	Additional Flow
SPUT	3
SQVT	2
SRWT	1
SRWVT	1

M1		adjusting flows on network (1 path shown correctly)
A1		correct
M1		additional flow in table
A1		second flow
A1	5	all correct

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(c)(iii)				
	Max flow of 39 (several possibilities of final flow diagram)	B1	1	
	Total		**13**	
	TOTAL		**75**	

Version 1.0: 0109

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2009 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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX *Dr Michael Cresswell Director General*

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.

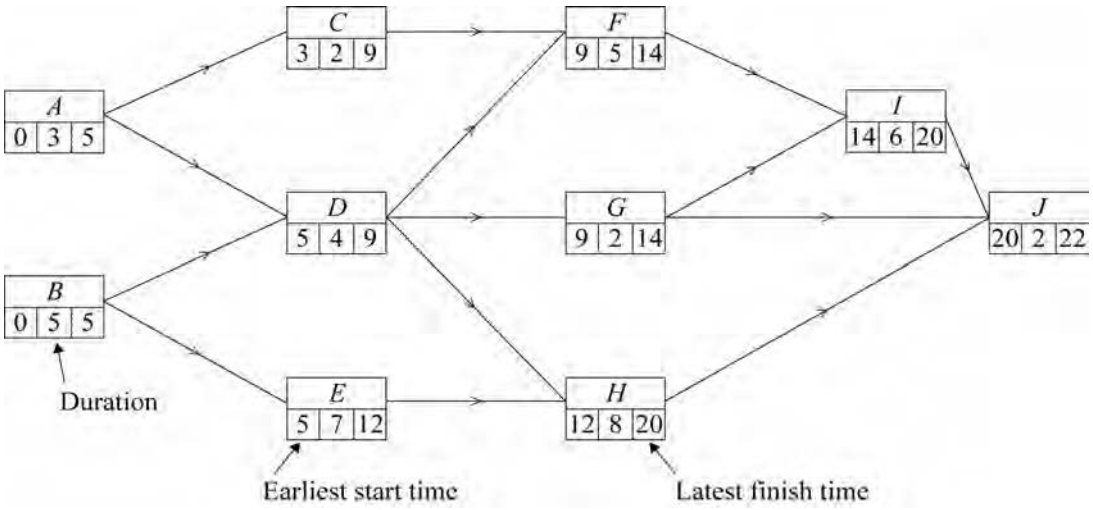
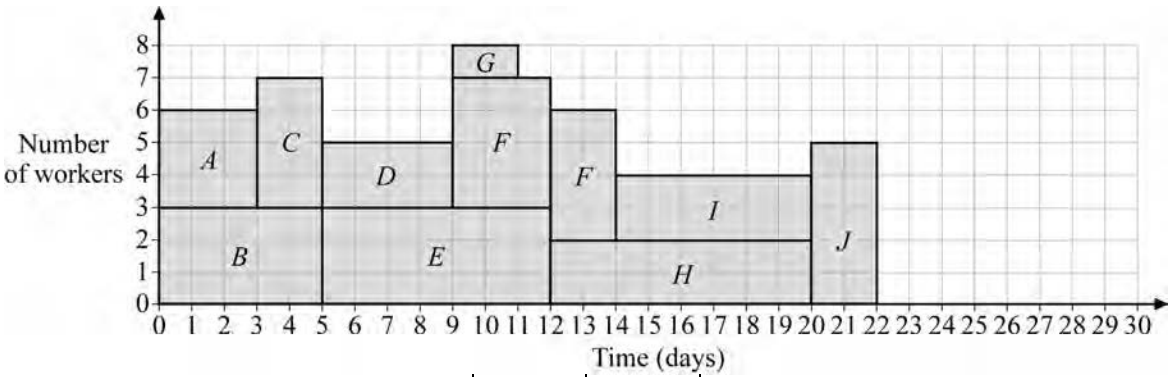
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MD02

Q	Solution	Marks	Total	Comments
1(a)	Reducing columns:			
	7 9 7 4 5 9 7 6 5 3 3 5 4 1 0 3 2 3 0 1 0 0 0 1 1	M1 A1		Reducing columns (allow up to 2 slips) All correct
	Reducing rows:			
	3 5 3 0 1 6 4 3 2 0 3 5 4 1 0 3 2 3 0 1 0 0 0 1 1	 A1	 3	 AG
(b)	x x x x x x x x x x x x			
	Covering with 3 lines as above	B1		
	Subtracting 2 from uncovered entries **and** adding 2 to double covered entries	M1		Condone one slip
	1 3 1 0 1 4 2 1 2 0 1 3 2 1 0 1 0 1 0 1 0 0 0 3 3	 A1	 	 Correct table
	Can be covered with 4 lines, so reduce uncovered entries by 1 and increase double covered entries by 1	m1		Condone one further slip
	0 2 0 0 1 3 1 0 2 0 0 2 1 1 0 1 0 1 1 2 0 0 0 4 4	 A1	 5	 CSO
(c)	S – 1, Q – 4 P3, Q4, R5, S1, T2 P5, Q4, R2, S1, T3	M1 A1 A1	 3	 First correct match 1S, 2T, 3P, 4Q, 5R Second match 1S, 2R, 3T, 4Q, 5P
(d)	Minimum time is 13 + 13 + 12 + 17 + 15 = 70	B1	1	Or 10 + 13 + 18 + 17 + 12 = 70
	Total		**12**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)				
(i)	Earliest start times	M1 A1	 2	Condone one slip with FT All correct
(ii)	Latest finish times	M1 A1	 2	Condone one slip with FT All correct
(b)	Critical paths *BEHJ* *BDFIJ* Minimum completion time 22 days	B1 B1 B1	 3	 And no others
(c)(i)	*BEHJ* or *BDFIJ* correctly fitted Second of critical paths *A* and *C* shown correctly F and G shown correctly no gaps in blocks etc	B1 B1 B1 B1	 4	Withhold first B1 mark if activities not clearly indicated
				
(ii)	Problem with C - now starts day 5 E delayed until day 7 E delayed until day 7 *F* cannot start until day 14 (*H*, *I* and *J* delayed) Extra time required 5 days	E1 E1 B1	 3	Or *C* starts day 12 and *F* starts day 14
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	P x y z r s Value			
	1 -4 5 -6 0 0 0	B1		B0 if no slack variables used
	0 6 7 -4 1 0 30	B1		
	0 (2) 4 –5 0 1 8	B1	3	
(b)(i)	Both negative when each value is divided by the entry in z-column	E1	1	
(ii)	Pivot from x-column since value in top row is negative			
	$\frac{30}{6} = 5$, $\frac{8}{2} = 4$ and $4 < 5$	E1		Both calculations and comparison needed
	Choose (2) as pivot	B1	2	
(iii)	1 0 13 -16 0 2 16	M1		Row operations keeping pivot row fixed or divided by 2
	0 0 –5 11 1 –3 6	A1		First or second row correct
	0 1 2 $-2\frac{1}{2}$ 0 $\frac{1}{2}$ 4	A1	3	All correct (final row may be 0 2 4 –5 0 1 8)
(iv)	$x = 4$	B1		
	$y = 0$, $z = 0$	B1	2	
(v)	As z increases, P increases without limit	E1	1	
(c)(i)	New initial tableau			
	Q x y z r s Value			
	1 $-\frac{}{4}$ 5 (20) 0 0 0			
	0 6 7 -4 1 0 30			
	0 2 4 -5 0 1 8	B1√		
	Revised tableau after one iteration			
	1 0 13 (10) 0 2 16	B1	2	Top row only changed to exactly this
(ii)	Max $Q = 16$	B1	1	
	Total		**15**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)	Row minima –7 **–1** –3 Column max 6 8 **–1**			
	Max (row min) = –1	M1		Attempting Row Min & Col Max or Maxmin and Minmax
	Min (col max) = –1	A1		All values correct and shown with correct words
	Since these values are equal the game has a stable solution	E1		Must both be –1 and have statement
	Raj plays II, Cal plays Z	B1	4	
(b)(i)	$C_1 : 5p - 2(1-p)$	B1		$7p - 2$
	$C_2 : xp + 4(1-p)$	B1	2	
(ii)	Value of game = $\frac{8}{3}$			
	$\Rightarrow 5p - 2(1-p) = \frac{8}{3}$	M1		Their expected gain $(C_1) = \frac{8}{3}$
	$\Rightarrow p = \frac{2}{3}$	A1		
	$xp + 4(1-p) = \frac{8}{3}$	M1		Their C_2 gain = $\frac{8}{3}$ (must involve x)
	$\Rightarrow \frac{2}{3}x + \frac{4}{3} = \frac{8}{3}$ $\Rightarrow x = 2$	A1	4	
	Total		**10**	

MD02 (cont)

<table>
<tr><th>Q</th><th>Solution</th><th>Marks</th><th>Total</th><th>Comments</th></tr>
<tr><td>5(a)</td><td>Greatest load on QACY is 12 tonnes
and on QBEY is 11 tonnes

QACY allows greater load to be carried</td><td>M1

A1</td><td>2</td><td>Either 12 or 11 stated

Both 12 and 11 seen plus statement</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><th>Stage</th><th>State</th><th>Action</th><th>Calculation</th><th>Value</th></tr>
<tr><td>1</td><td>C</td><td>CY</td><td>-</td><td>12</td></tr>
<tr><td></td><td>D</td><td>DY</td><td>-</td><td>15</td></tr>
<tr><td></td><td>E</td><td>EY</td><td>-</td><td>16</td></tr>
<tr><td>2</td><td>A</td><td>AC</td><td>Min(14,12)</td><td>12*</td></tr>
<tr><td></td><td></td><td>AD</td><td>Min(11.15)</td><td>11</td></tr>
<tr><td></td><td></td><td>AE</td><td>Min(10,16)</td><td>10</td></tr>
<tr><td></td><td>B</td><td>BC</td><td>Min(12,12)</td><td>12</td></tr>
<tr><td></td><td></td><td>BD</td><td>Min(13,15)</td><td>13*</td></tr>
<tr><td></td><td></td><td>BE</td><td>Min(11,16)</td><td>11</td></tr>
<tr><td>3</td><td>Q</td><td>QA</td><td>Min(13,12)</td><td>12</td></tr>
<tr><td></td><td></td><td>QB</td><td>Min(14,13)</td><td>13*</td></tr>
</table>

Maximin route QBDY
Maximum possible load = 13 tonnes</td><td>M1
A1
A1

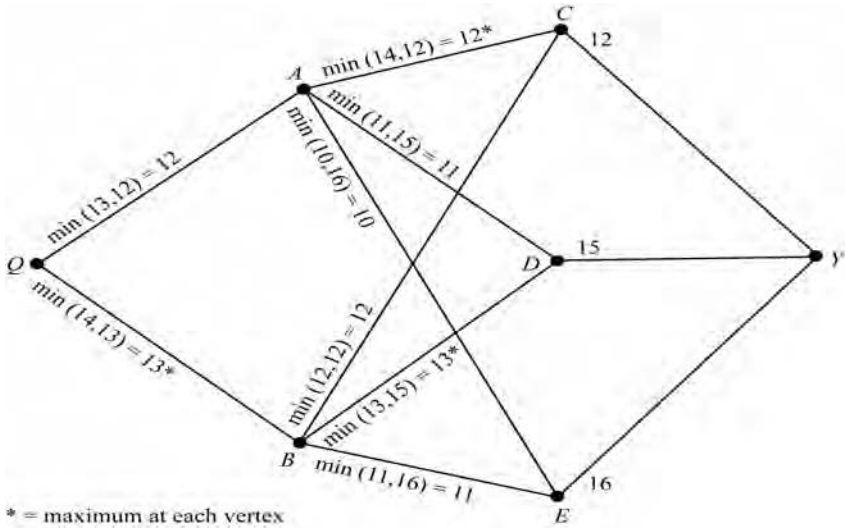
m1

A1

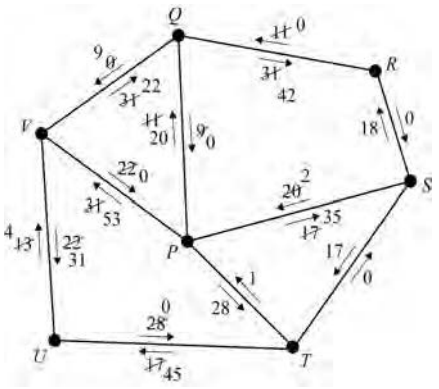
B1
B1</td><td>8</td><td>Stage 1 values (12), 15 and 16

Stage 2: at least 3 min values correct
At least 5 values correct
All calculations showing minima and values correct

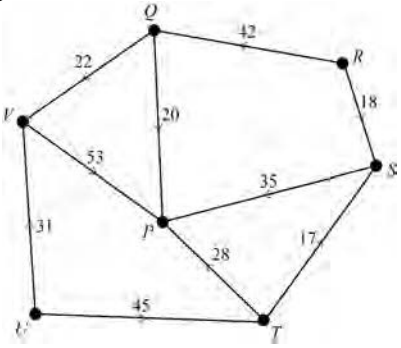
Stage 3: “12” and “13” brought forward from Stage 2

All calculations and values correct</td></tr>
<tr><td></td><td>Total</td><td></td><td>10</td><td></td></tr>
<tr><td></td><td colspan="4">Network approach – must work backwards from Y:
 
</td></tr>
</table>

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	Arrival gates are *U* and *R*	B1	1	
(b)	Cut value = 45 + 53 + 20 + 37 + 0 = 155	B1	1	
(c)	Max flow along *UTSP* is 17 and along *RQVP* is 31	B1 B1	2	
(d)(i)				

Route	Value of Flow
UTSP	17
RQVP	31
RSP	18
RQP	11
UTP	28
UVP	22
UVQP	9

	Initial flows along *UTSP* and *RQVP* with potential increases and decreases	B1		
	Table: first route and correct flow Another route and flow Table correct	M1 A1 A1		After *UTSP* and *RQVP*
	Network: attempt to use labelling procedure with forward/backward flows All diagram correct	M1 A1	6	
(ii)	Maximum flow = 136 Figure 5 correct: 	B1 B1	2	Other possible answers
(e)	Rate reduced by 3 New maximum is 133	M1 A1	2	"their" maximum flow – 3
	Total		**14**	
	TOTAL		**75**	

Version : 1.0 0609

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2009 examination - June 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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX *Dr Michael Cresswell Director General*

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.

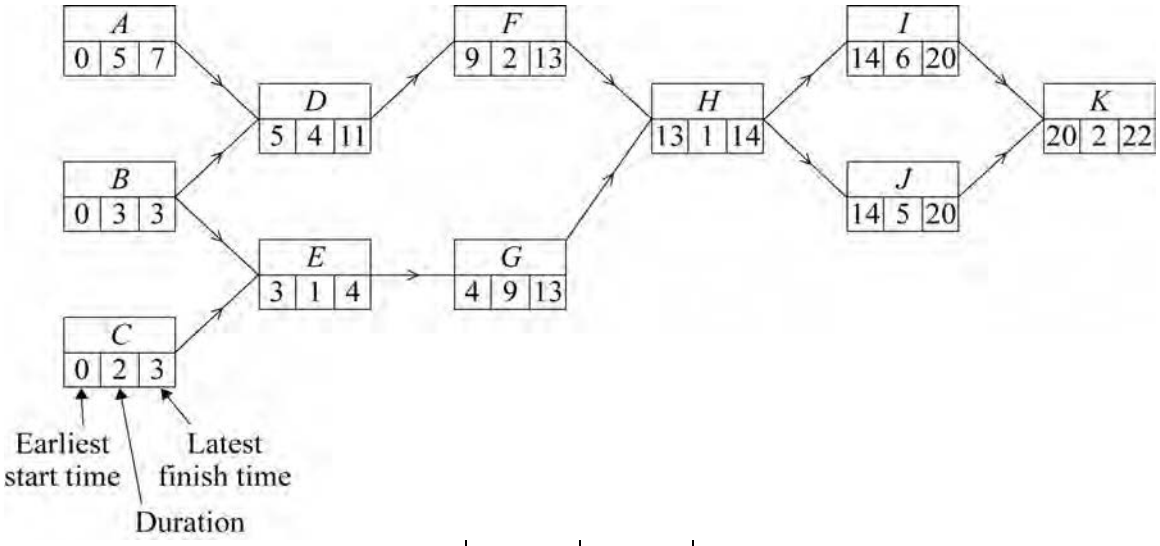
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

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

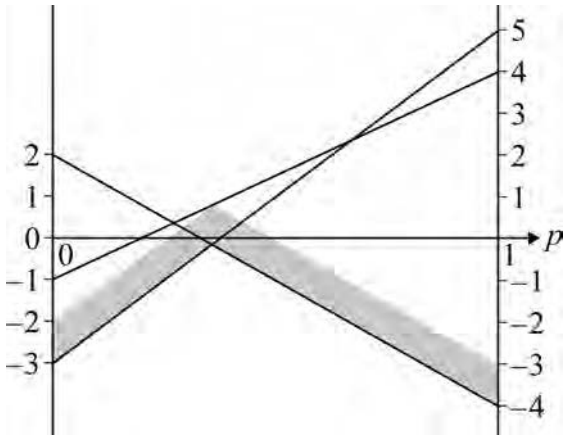
Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

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

MD02

Q	Solution	Marks	Total	Comments
1				
(a)	Network attempted (3 more activities) Up to 2 slips (boxes or connections) Correct network	M1 A1 A1	3	SCA Condone missing arrows if sequence is clear
(b)(i)	Forward pass Correct	M1 A1	2	up to 1 slip ft
(ii)	Backward pass Correct	M1 A1	2	up to 1 slip ft
(c)	Minimum completion time 22 days Critical path *B E G H I K*	B1 B1	2	Must be stated – not simply in *K* box and no others
(d)(i)	New start time for *H* is 15 days New start time for *I* is 16 days	M1 A1	2	For *H*, their (*F* earliest time 9) + (2 + 4) both correct
(ii)	Minimum delay is 2 days	B1	1	Condone new completion time 24 days
	Total		**12**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	(For each outcome) Rowena's gain + Colin's gain = 0	E1	1	One player's loss is other's gain
(b)	(Column maxima 2, 5, 4) $\Rightarrow \min(\text{col max}) = 2$ (OE but strict) $\Rightarrow$ Colin's play-safe strategy is C_1	E1 B1	2	Withhold E mark if any value incorrect; accept column minimax = 2
(c)	R_3 is dominated by R_1	E1	1	$-5 < -4$; $4 < 5$ and $3 < 4$ E0 if R_2 mentioned as well
(d)	Let Rowena play R_1 with prob p and R_2 with prob $1-p$ Expected gain when Colin plays $C_1: -4p + 2(1-p) = 2-6p$ $C_2: 5p - 3(1-p) = -3+8p$ $C_3: 4p - (1-p) = -1+5p$	M1 A1		attempt at least 2 with one correct all 3 correct unsimplified
	Plot expected gains against p for $0 \leqslant p \leqslant 1$	M1		All 3 drawn ft their exp gains
		A1		correct
	$\Rightarrow 2-6p = -3+8p$	M1		Using "correct" equation Choosing highest point of region
	$\Rightarrow p = \frac{5}{14}$	A1		
	Therefore Rowena plays R_1 with prob $\frac{5}{14}$ and R_2 with prob $\frac{9}{14}$	E1√	7	ft their p
	Total		**11**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	Hungarian algorithm minimises. $17-x$ gives measure of criteria not met (which need minimising in order to maximise scores)	E1 E1	2	Or changes maximising to minimising problem Explanation of what each new entry or 17- x represents (as something which can be minimised)
(b)	4 4 8 7 4 4 3 5 0 2 1 7 9 3 3 6 3 5 1 7 5 3 3 4 2	B1		array with $17-x$ values
	0 0 4 3 0 → 0 0 3 3 0 4 3 5 0 2 → 4 3 4 0 2 0 6 8 2 2 → 0 6 7 2 2 5 2 4 0 6 → 5 2 3 0 6 3 1 1 2 0 → 3 1 0 2 0	M1 A1	3	reduce rows first – condone one slip then columns; AG
(c)	Top and bottom rows and 1st & 4th columns covered 2 0 3 5 0 4 1 2 0 0 0 4 5 2 0 5 0 1 0 4 5 1 0 4 0	B1 M1 A1CSO	3	Zeros covered with 2 horizontal and 2 vertical lines augment by subtracting 2 from each uncovered and adding 2 to each double covered – condone one slip (may earn if 4 different lines are drawn)
(d)	T1, R2, V3, U4, S5 T1, U2, V3, S4, R5	M1 A1 M1 A1	4	3 items correctly matched First matching correct 3 items correct in second matching Second matching correct and no other matches attempted
(e)	Maximum total score = 74	B1	1	
	Total		**13**	

MD02 (cont)

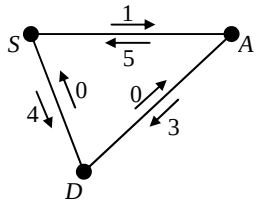
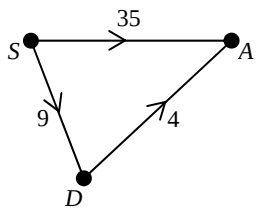
Q	Solution	Marks	Total	Comments
4(a)	$x+2y+3z\leqslant 7$ $2x+y+4z\leqslant 10$	B1	1	Exactly this
(b)(i)	Pivot is 2 in x-column	B1		Must be ringed or clearly indicated or stated – **not** simply implied
	P x y z s t *value* 1 0 1 $8-k$ 0 2 20 0 0 $1\frac{1}{2}$ 1 1 $-\frac{1}{2}$ 2 0 1 $\frac{1}{2}$ 2 0 $\frac{1}{2}$ 5	M1 A1 A1	4	row operations (even with incorrect pivot) condone one slip Top or 2nd row correct using correct pivot All correct (condone multiples of rows)
(ii)	$8-k<0$	M1		Their $f(k)<0$
	$\Rightarrow k>8$	A1	2	SC B1 for $k \geq 9$
(c)(i)	New pivot from z-column in second row	B1√		Stated or possibly implied from tableau
	P x y z s t *value* 1 0 4 0 2 1 24 0 0 $1\frac{1}{2}$ 1 1 $-\frac{1}{2}$ 2 0 1 $-2\frac{1}{2}$ 0 –2 $1\frac{1}{2}$ 1	M1 A1 A1	4	row operations using "their" **correct pivot** condone 1 slip one row (other than pivotal row) correct all correct (condone multiples of rows)
(ii)	$P = 24$	B1√		Provided no negatives in top row
	Optimum now reached	E1		Or $P_{max} =$ .....
	$x=1,\ y=0,\ z=2$	B1√	3	Only ft if no more than 2 slips in final tableau
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)	Completing stage 2 values (condone unsimplified)	B1		
	At least 6 values at stage 3	M1		
	using only "their" max *I* value from stage 2	m1		
	All stage 3 values correct	A1		
	Using only max at *D, E, F, G* from stage 3 in stage 4 (at least 3 of these values used)	M1		
	All stage 4 values correct	A1		
	All stage 5 values correct and all other values correct unsimplified	A1CSO	7	
(b)	Maximum profit £18m	B1		condone 18
	Sequence of actions *S A E H K T*	B1	2	
	Total		**9**	

Stage	State	From	Value	
1	*K*	*T*	7	
	L	*T*	8	
2	*H*	*K*	–2 + 7 = 5	
	I	*K*	4 + 7 = 11	*
		L	–1 + 8 = 7	
	J	*L*	5 + 8 = 13	
3	*D*	*H*	4 + 5 = 9	
		I	2+11 = 13	*
	E	*H*	7 + 5 = 12	*
		I	–9+11 = 2	
	F	*I*	–4+11 = 7	
		J	9+13 = 22	*
	G	*I*	–7+11 = 4	
		J	–8+13 = 5	*
4	*A*	*D*	–2+13=11	
		E	5+12 = 17	*
		F	–8+22=14	
	B	*E*	–1+12=11	
		F	–7+22=15	*
		G	–3 + 5 = 2	
	C	*G*	5 + 5 = 10	
5	*S*	*A*	1+17 = 18	*
		B	2+15 = 17	
		C	6+10 = 16	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	Value of cut = 30 – 10 + 12 + 20 = 52	M1 A1	2	Full marks for correct answers without working
(b)	*AE* = 9; *EF* = 5; *FG* = 4	B1 B1 B1	3	
(c)(i)	Attempt at forward and backward flows *SA* 2 & 4 ; *AB* 1 & 3 ; *BT* 1 & 3 *SD* 3 & 1 ; *DA* 0 & 3 ; *AE* 0 & 3 *BE* 0 & 7 ; *DE* 2 & 0 ; *ET* 1 & 3 *FD* 2 & 1 ; *EF* 5 & 1 ; *EG* 1 & 5 *FG* 1 & 2 ; *GT* 3 & 0	M1 A1 A1	3	At least 5 pairs correct 10 pairs correct all correct
(ii)	First flow augmenting path and correct flow on table Table correct Adjusting flows – forward and back Correct	M1 A1 M1 A1	4	May end up with  Path / Extra flow *SABT* 1 *SADET* 1 Or *SDET* *SDFGT* 1 *SDEGT* 1
(d)	Max flow of 44 shown on figure 5	M1 A1	2	up to 2 slips all correct
(e)	Cut through their saturated arcs Cut passes through *AB*, *AE*, *DE* and *DF*	M1 A1	2	May have  Or *BT*, *ET*, *EG*, and *FG*
	Total		**16**	
	TOTAL		**75**	

Version 1.0: 0110

General Certificate of Education

Mathematics 6360

MD02 Decision 2

Mark Scheme

2010 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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX *Dr Michael Cresswell Director General*

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.

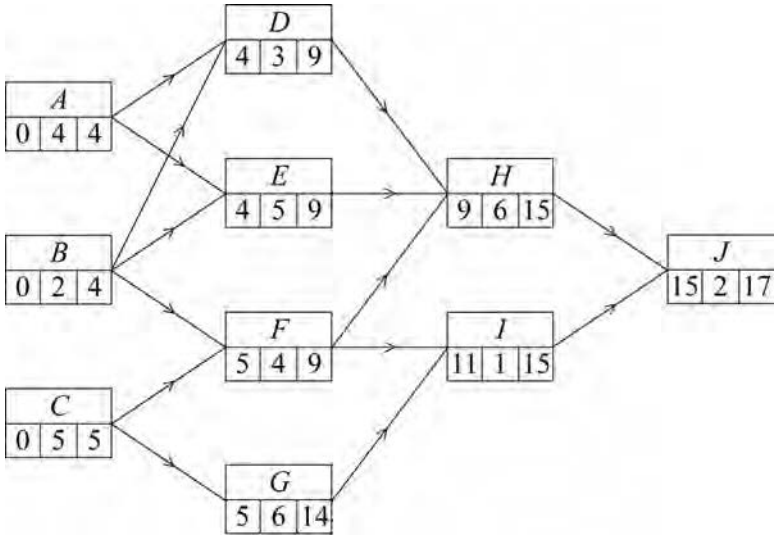
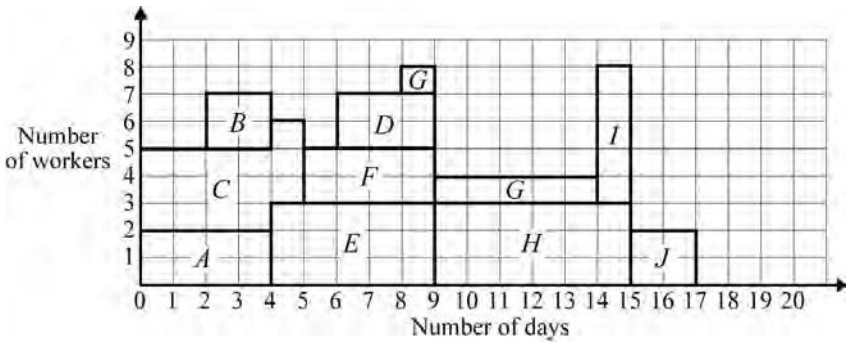
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

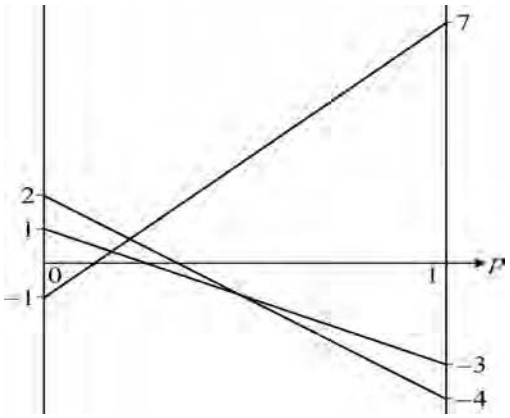
MD02

Q	Solution	Marks	Total	Comments
1				
(a)(i)	Earliest start times	M1 A1	 2	At least 4 correct (other than zeros) All correct
(ii)	Latest finish times	M1 A1	 2	Up to one error + follow through All correct
(b)	Float for G = 3 days	B1√	1	ft their G values
(c)	Critical paths $A\ E\ H\ J$ and $C\ F\ H\ J$ Minimum completion time = 17 days	B1 B1 B1	 3	First correct path Second path (and no others) Must be stated explicitly
(d)				
	One of their CPs – correct heights $A\ E\ H\ J$ and $C\ F\ (H\ J)$ correct	M1 A1		**NB** "holes" penalise first A1 earned
	B starting at 2 (and ending at 4) D starting at 6 (and ending at 9) G starting at 8 (and ending at 14) I starting at 14 (and ending at 15)	M1 A1 A1	 5	One correct with correct height Two correct with correct height All correct with correct height and no slack Withhold first A1 earned if it is not clear which activities take place at any given time
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	8 7 9 10 8 9 x 8 7 11 12 10 9 9 10 11 9 8 11 11 12 12 12 12 12	B1	1	Adding extra row equal values
(b)(i)	0 0 1 3 0 1 $x-7$ 0 0 3 4 3 1 2 2 3 2 0 4 3 4 5 4 5 4	B1√		Reducing columns first
	0 0 1 3 0 1 $x-7$ 0 0 3 3 2 0 1 1 3 2 0 4 3 0 1 0 1 0	B1√		Reducing rows
	Zeros covered with 4 lines (stated or drawn) **0 0 1 3 0** **1 $x-7$ 0 0 3** 3 2 **0** 1 1 3 2 **0** 4 3 **0 1 0 1 0**	E1		or **0 0** 1 **3 0** 1 x-7 **0 0** 3 3 2 **0** 1 1 3 2 **0** 4 3 **0 1 0 1 0**
		M1		Augmentation – adding 1 to double covered and subtracting 1 from uncovered
	⇒ 0 0 2 3 0 1 $x-7$ 1 0 3 2 1 0 0 0 2 1 0 3 2 0 1 1 1 0	A1	5	or 0 0 2 4 0 0 $x-8$ 0 0 2 2 1 0 1 0 2 1 0 4 2 0 1 1 2 0
(ii)	S1, V2, Z3, T4	M1		At least 2 matched correctly or "rings" on final tableau
		A1	2	(Ron not assigned)
(iii)	Total time 32 (minutes)	B1	1	
(c)	V3, T4, R1	B1		First matching
	or V3, T4, Z1	B1	2	Second matching and no other
	Total		**11**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	Row min – 2 – 3 –5 Col max 4 0 –2	B1		Row minima and column maxima (all values)
	Max (row min) = – 2 Min (col max) = – 2	M1		Both attempted or stated/indicated
	Since these are equal, there is a stable solution	A1		Must have both values = – 2 plus statement (withhold if max (min) and min (max) not stated)
	Ann plays A_1 and Bill plays B_3 for play-safe	E1	4	
(b)(i)	Let Russ play R_1 with probability p			And R_2 with probability $1-p$
	C_1: expected gain $-4p + 2(1-p)$			$(2-6p)$
	$C_2 : 7p - (1-p) = 8p-1$	M1		2 correct unsimplified
	$C_3 : 3p + (1-p) = 1-4p$	A1		All correct
		M1		Plotting 3 expected gains for $0 \le p \le 1$
		A1		Correct gains plotted accurately
	Solving $8p - 1 = 1 - 4p$	M1		Choosing highest point of their region or correct
	$\Rightarrow p = \frac{1}{6}$	A1		
	$\Rightarrow$ Russ plays R_1 with probability $\frac{1}{6}$ and R_2 with prob $\frac{5}{6}$	E1	7	
(ii)	Value of game $= \frac{8}{6} - 1$ $= \frac{1}{3}$	B1	1	Or $1 - \frac{4}{6}$
	Total		**12**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	Slack (variables)	E1	1	Must be correct word
(ii)	$2x + 2y + z + s = 14$	B1	1	Exactly this
(b)(i)	Pivot from y-column = 1	B1		Identified or seen used by keeping 3rd row fixed
	$\begin{matrix} 1 & -6 & 0 & 5 & 0 & 4 & 0 & 24 \\ 0 & 4 & 0 & -3 & 1 & -2 & 0 & 2 \\ 0 & -1 & 1 & 2 & 0 & 1 & 0 & 6 \\ 0 & 8 & 0 & -5 & 0 & -4 & 1 & 5 \end{matrix}$	M1		Row operations, even with wrong pivot
		A1		1st, 2nd or 4th row correct
		A1	4	All correct
(ii)	Still negative value in top row	E1	1	(only award if this is true for their tableau)
(c)(i)	Choosing 4 as pivot in x-column	M1		And perhaps dividing by 4 (using their pivot)
	$\begin{matrix} 1 & 0 & 0 & \frac{1}{2} & \frac{3}{2} & 1 & 0 & 27 \\ 0 & 1 & 0 & \frac{-3}{4} & \frac{1}{4} & \frac{-1}{2} & 0 & \frac{1}{2} \\ 0 & 0 & 1 & \frac{5}{4} & \frac{1}{4} & \frac{1}{2} & 0 & \frac{13}{2} \\ 0 & 0 & 0 & 1 & -2 & 0 & 1 & 1 \end{matrix}$	A1		1st, 3rd or 4th row correct ft one slip
		A1		1st, 3rd or 4th row (another correct) ft one slip
		A1	4	All correct (condone multiples of rows)
(ii)	Optimum now reached (since no negatives in top row)	E1		Or maximum value of P indicated (must have no negatives in top row)
	$P = 27$	B1√		ft their tableau P
	$x = \frac{1}{2},\ y = 6\frac{1}{2},\ z = 0$	B1	3	CAO; final tableau "correct" one slip
	Total		**14**	
5	July values	B1		3 correct unsimplified
		B1		Another 3 correct
		B1		All correct
	Use of one July min in June calculation	M1		
		A1		4 correct values in June
		A1		All June values correct (ft one slip)
	Use of two June min values in May calculation	M1		
		A1		All May correct (ft one slip)
				Equivalent scheme for Network Method working backwards from August
	Their least May value ⇒ Project for May	M1		
	May June July August *C* *A* hol *B*	A1	10	Schedule correct
				SC B1 if schedule correct with no dynamic programming

MD02 (cont)

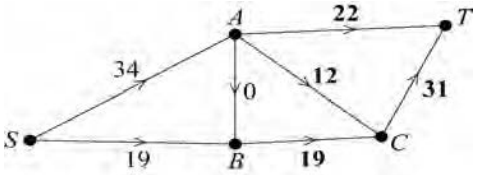
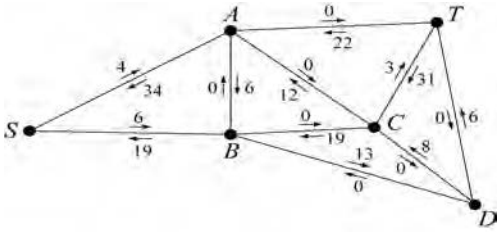
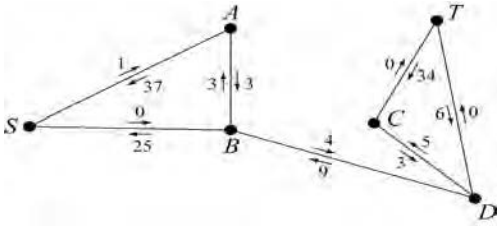
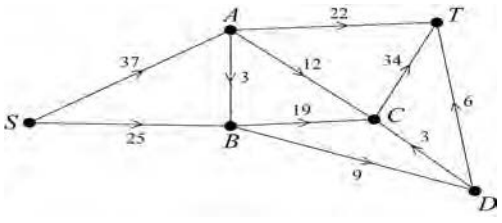
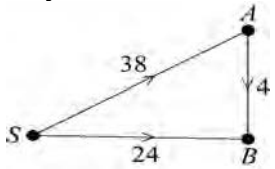
Q	Solution	Marks	Total	Comments
5 (cont)				

Stage (Month)	**State (Projects already done)**	**Action (Project to do)**	**Calculation**	**Cost in thousands of pounds**
August	*A, B, C*	0		0 (given)
	A, B	*C*		14 (given)
	A, C	*B*		10 (given)
	B, C	*A*		16 (given)
July	*A, B*	0	0 + 14	14 (given) ←
		C	15 + 0	15 (given)
	A, C	0	0 +10	10 ←
		B	12 + 0	12
	B, C	0	0 + 16	16 ←
		A	18 + 0	18
	A	*B*	12 + 14	26(given)
		C	15 + 10	25 ←
	B	*A*	18 + 14	32
		C	15 + 16	31 ←
	C	*A*	18 + 10	28 ←
		B	12 + 16	28 ←
June	*A*	0	0 + 25	25 ←
		B	13 + 14	27
		C	17 + 10	27
	B	0	0 + 31	31
		A	16 + 14	30 ←
		C	17 + 16	33
	C	0	0 + 28	28
		A	16 + 10	26 ←
		B	13 + 16	29
	0	*A*	16 + 25	41 ←
		B	13 + 31	44
		C	17 + 28	45
May	0	0	0 + 41	41
		A	17 + 25	42
		B	14 + 30	44
		C	14 + 26	40 ←

Schedule				
	May	**June**	**July**	**August**
Project	*C*	*A*	holiday	*B*

	Total		**10**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)(i)	Value of cut = 38 + 25 + 0 + 0 + 34 = 97	B1	1	Must show correct addition AG
(ii)	$\{S, A\}$, $\{B, C, T\}$ 65	B1		
	$\{S, B\}$, $\{A, C, T\}$ 57	B1		
	$\{S, B, C\}$, $\{A, T\}$ 72	B1		
	$\{S, A, B, C\}$, $\{T\}$ 56	B1	4	
(iii)	Maximum flow = 53	B1√		ft their least cut value
	Minimum cut = Max flow	E1	2	
(iv)	Their max flow on *SA*, *SB* or *AT*, *CT*	M1		
	All correct	A1	2	
	AT 22; AC 12; BC 19; CT 31			
	$AB = x$; $AS = x + 34$; $SB = 19 - x$			
	$0 \le x \le 4$			
(b)(i)	Initial flow on Figure 6	M1		
	Forward potential and backward flow			
	Condone 2 slips, ft their Figure 5			
	One correct augmented path in table and correct flow	M1		
		A1		
	Table correct with total additional flow= 9			
	Final network correct with evidence of labelling procedure used	A1	4	
(ii)	New maximum flow = 62	B1		
	Correct maximum flow on network	B1	2	
	May have			
	Total		**15**	
	TOTAL		**75**	

Path	Additional Flow
SBDT	6
SABDCT	3

Version 1.0

General Certificate of Education
June 2010

Mathematics MDO2

Decision 2

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 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.

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334). Registered address: AQA, Devas Street, Manchester M15 6EX

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.

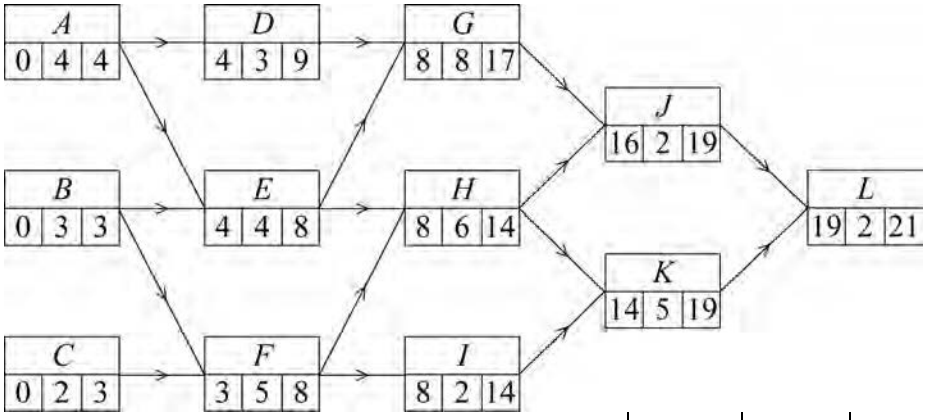
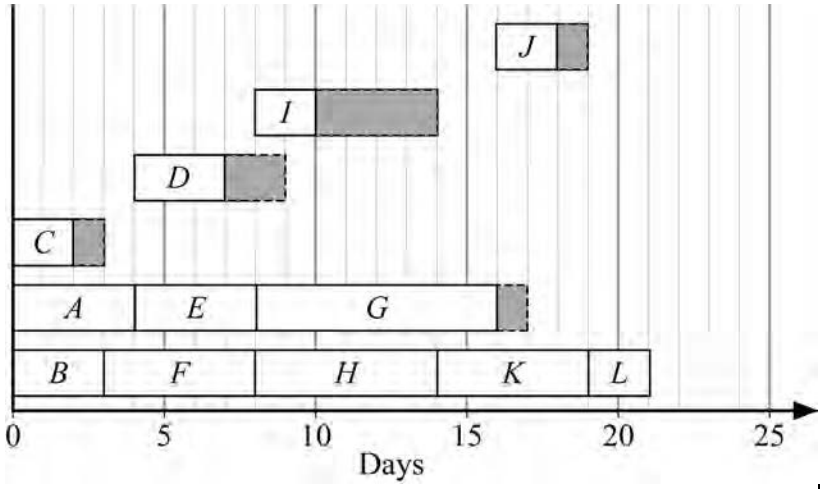
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **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)				
	Earliest start times	M1		one slip follow through
		A1		all correct
	Latest finish times	M1		one slip follow through
		A1	4	all correct
(b)	Critical paths are *AEHKL* and *BFHKL*	M1		one correct
		A1		both correct and no extras
	Minimum completion time = 21 days	B1	3	
(c)				$A(0 \rightarrow 4)$ $B(0 \rightarrow 3)$ $C(0 \rightarrow 2 \rightarrow 3)$ $D(4 \rightarrow 7 \rightarrow 9)$ $E(4 \rightarrow 8)$ $F(3 \rightarrow 8)$ $G(8 \rightarrow 16 \rightarrow 17$ $H(8 \rightarrow 14)$ $I(8 \rightarrow 10 \rightarrow 14$ $J(16 \rightarrow 18 \rightarrow 19$ $K(14 \rightarrow 19)$ $L(19 \rightarrow 21)$
		B1		*A, B, E, F, H, K, L* correct
		M1		*C, D, G, I, J* (4 with correct start and duration)
		A1	3	All 5 correct with correct slack indicated
(d)(i)	*K* now starts day 17	B1		or "delayed" b 3 days if 14 in network
	L now starts day 22	B1	2	or "delayed" b 3 days if 19 in network
(ii)	Overall delay 3 days	B1	1	
	Total		**13**	

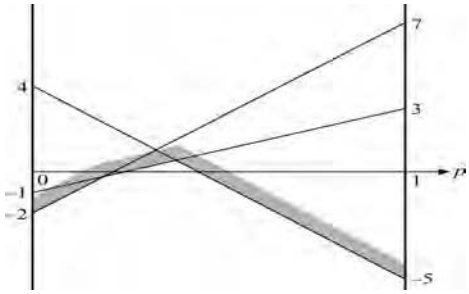
MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	2 4 0 5 5 4 2 0 4 3 5 0 1 9 2 1 1 0 7 4 0 2 0 3 5	M1		rows reduced (allow one slip)
	2 4 0 2 3 4 2 0 1 1 5 0 1 6 0 1 1 0 4 2 0 2 0 0 3	m1 A1	3	columns reduced next Correct table $k = 6$ stated or correct in table
(b)	3 lines needed to cover zeros shown	B1		middle column, middle and bottom rows
	Reduce each uncovered element by 1 and increase double covered by 1	M1		Condone one slip
	1 3 0 1 2 3 1 0 0 0 5 0 2 6(k) 0 0 0 0 3 1 0 2 1 0 3	A1	3	FT "their k". Condone k instead of 6
(c)	*A*3	M1		Or correct "rings" round elements for one complete solution
	(A3) *B*4 *C*5 *D*2 *E*1	A1		first correct matching – must be stated
	(A3) *B*5 *C*2 *D*1 *E*4	A1	3	second correct matching and no others
(d)	Minimum total penalty points = 22	B1	1	
	Total		**10**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	P x y z s t *valu e* 1 –6 –5 –3 0 0 0 0 ①(1) 2 k 1 0 8 0 2 10 1 0 1 17	M1 A1 A1	3	Two slack variables used correctly 1 row correct all correct May earn in (b)(i)
(b)(i)	Pivot in x-column = 1	B1		May be implied by second row unchanged
	1 0 7 $6k$–3 6 0 48 0 1 2 k 1 0 8 0 0 6 1–2k –2 1 1	M1 A1 A1	4	row operations (even with wrong pivot) 1st or 3rd row correct all correct
(ii)	$6k-3<0$ $\Rightarrow k<\frac{1}{2}$	M1 A1	2	"their" $6k-3<0$
(c)	1 0 7 –9 6 0 48 0 1 2 –1 1 0 8 0 0 6 ③(3) –2 1 1	M1		new pivot correct from their tableau and row operations attempted
	1 0 25 0 0 3 51 0 1 4 0 $\frac{1}{3}$ $\frac{1}{3}$ $8\frac{1}{3}$ 0 0 2 1 $-\frac{2}{3}$ $\frac{1}{3}$ $\frac{1}{3}$	A1 A1	3	2 rows correct (may be multiples of rows) usually pivot row & 1 other all correct (condone multiples of rows) Condone FT from one slip in (b)(i)
	Max P now achieved	E1		Or "optimum", "P_{max} =...."etc" Bur must have no negatives in top row
	$P = 51$ $x = 8\frac{1}{3}$, $y = 0$, $z = \frac{1}{3}$ (all three)	B1✓ B1	3	FT their tableau correct values from almost 'correct' tableau (condone one slip) condone 8.33 or better
	Total		**15**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	Let Roger play R_1 with probability p and R_2 with probability $1-p$			
	Expected gains:			
	$C_1 : 7p-2(1-p)=9p-2$	M1		one correct unsimplified
	$C_2 : 3p-(1-p)=4p-1$			
	$C_3 : -5p+4(1-p)=4-9p$	A1		all correct unsimplified
		M1 A1		2 of their lines drawn correctly all correct and accurate for $0 \le p \le 1$ Condone lines not quite to p = 1 if using "accurate" intersection points on p-axis i.e. $\frac{2}{9} < \frac{1}{4}$ and $\frac{4}{9} \approx twice \frac{2}{9}$
	C_2 and C_3 lines give optimum			
	$4p-1=4-9p$	M1		ft their max point of region
	$p=\frac{5}{13}$	A1		Condone 0.385 or 0.3846(15…) must be correct rounding if 3sf used
	Roger plays			
	$R_1 \frac{5}{13}$ of time and $R_2 \frac{8}{13}$ of time	E1	7	CAO
(ii)	Value of game $= 4\times\frac{5}{13}-1=\frac{7}{13}$	B1	1	AG or $\left(4-9\times\frac{5}{13}\right)=\frac{7}{13}$ must see correct calculation
(b)	Let Corrie play C_1 with prob p, C_2 with prob q, C_3 with prob $1-p-q$			
	$R_1 : 7p+3q-5(1-p-q)$	M1		any correct expression
	$R_2 : -2p-q+4(1-p-q)$			
	$\Rightarrow 12p+8q=5\frac{7}{13}$	A1		either equation correctly with coefficients of p and q correctly simplified
	$6p+5q=3\frac{6}{13}$			
	$\Rightarrow \left.\begin{matrix} q=\frac{9}{13} \\ p=0 \end{matrix}\right\}$	m1 A1CSO		*may reason that p(C1) = 0 from part(a)E1 with M1, A1, A1, E1 from 2 × 2 equations* $3r-5s=\frac{7}{13}$ $-r+4s=\frac{7}{13}$
	$\Rightarrow$ Optimal mixed strategy is			
	C_1 with prob 0			
	C_2 with prob $\frac{9}{13}$			Condone 0.692
	C_3 with prob $\frac{4}{13}$	E1	5	CAO & 0.308
	Total		**13**	

MD02 (cont)

<table>
<tr><th>Q</th><th>Solution</th><th>Marks</th><th>Total</th><th>Comments</th></tr>
<tr><td>5(a)</td><td>PQSV has longest journey 12
PQTV has longest journey 13</td><td>B1</td><td></td><td>Both of these</td></tr>
<tr><td></td><td>Since 12 < 13, PQSV is better</td><td>E1</td><td>2</td><td>OE</td></tr>
<tr><td>(b)</td><td colspan="4">
<table>
<tr><th>Stage</th><th>State</th><th>Action</th><th>Calculation</th><th>Value</th></tr>
<tr><td>1</td><td>S</td><td>SV</td><td>-</td><td>11</td></tr>
<tr><td></td><td>T</td><td>TV</td><td>-</td><td>9</td></tr>
<tr><td></td><td>U</td><td>UV</td><td>-</td><td>12</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>2</td><td>Q</td><td>QS</td><td>Max (12, 11)</td><td>12</td></tr>
<tr><td></td><td></td><td>QT</td><td>Max (13, 9)</td><td>13</td></tr>
<tr><td></td><td></td><td>QU</td><td>Max (7, 12)</td><td>12</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td></td><td>R</td><td>RS</td><td>Max (10, 11)</td><td>11</td></tr>
<tr><td></td><td></td><td>RT</td><td>Max (14, 9)</td><td>14</td></tr>
<tr><td></td><td></td><td>RU</td><td>Max (8, 12)</td><td>12</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>3</td><td>P</td><td>PQ</td><td>Max (9, 12)</td><td>12</td></tr>
<tr><td></td><td></td><td>PR</td><td>Max (11, 11)</td><td>11</td></tr>
</table>
</td><td>B1

M1

A1

M1

A1

A1</td><td></td><td>2 values correct

All correct with pairs of correct values compared in calculation column

2 values correct

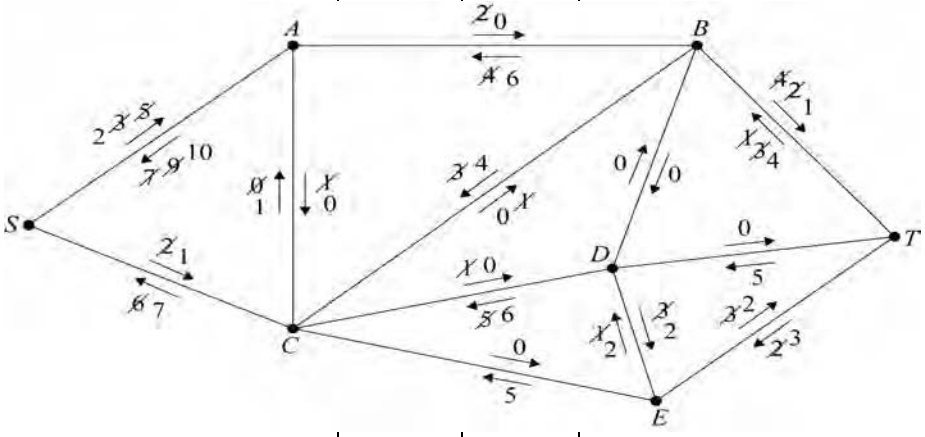
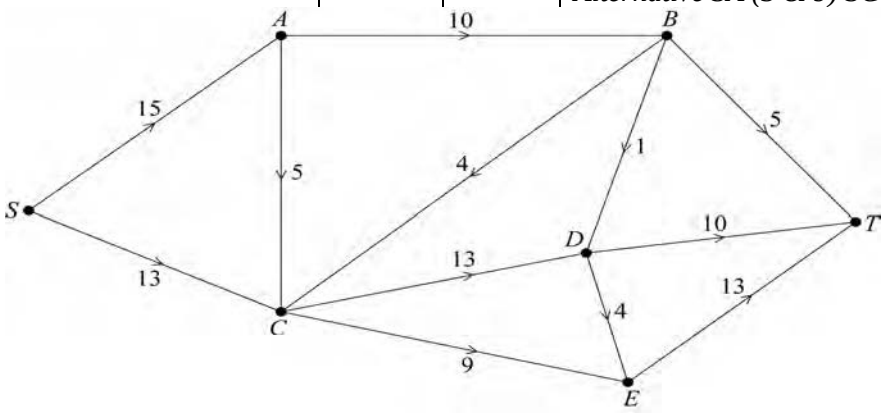
All correct with pairs of correct values compared to calculation column

CSO; all table correct
With word “MAX” seen at least once (or 12 >11 etc)</td></tr>
<tr><td></td><td>Using their minimum at stage 3

Minimax route from P to V is PRSV</td><td>M1

A1</td><td>8</td><td>Implied by route starting PR
(Or PQ if that is their least value)
SC B1 for correct minimax route when several values in table are incorrect</td></tr>
<tr><td></td><td>Total</td><td></td><td>10</td><td></td></tr>
<tr><td colspan="5">Network approach: Use same mark scheme for 6 marks insisting on precisely these values, pairs of correct values seen and considered with maximum selected for first two A marks, and word ‘Max’ seen and all correct for final A mark</td></tr>
</table>

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	Value of cut = 10 + 10 + 15 – 4 – 1 = 30	M1 A1	2	condone one slip if working shown
(b)	*BT* 2 , *DE* 3 , *ET* 12	B1 B1	2	any 2 correct all correct
(c)(i)	Initial flows forward and back or double Arc with arrows(at **least 6 pairs correct**)	M1 A1	2	Condone pairs of values, (coordinates) with single arrow all correct (condone pairs with single arrow provided key indicated)
(ii)	**Path** / **Flow** *SABT* 2 *SCDET* 1 *SACBT* 1 (or SCBT instead of SACBT with flow 1	M1 A1 A1		first correct path and flow another correct path and flow all correct (*other possibilities also*)
				
	Must have forward and backward flows	M1 A1	5	augmenting flows (6 pairs correct) correct
(iii)				*Alternative SA (3 & 9) SC (0&8)*
	May have *SA*(14), *SC*(14) and *AC*(4) using alternative Maximum flow values	M1 A1	2	at least 8 correctly interpreted from their Figure 4 but 24 < *their maxflow* < 29
(d)	Cut through *AB, CB, CD* and *CE* May use {*S,A,C*} / {*B,D,E,T*}	B1 B1	1	**But** must have total flow of 28 in their network (condone one slip)

	Total		**14**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education (A-level)
January 2011

Mathematics MD02

(Specification 6360)

Decision 2

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 candidates' 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 candidates' 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.

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.

Further copies of this Mark Scheme are available from: aqa.org.uk

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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.

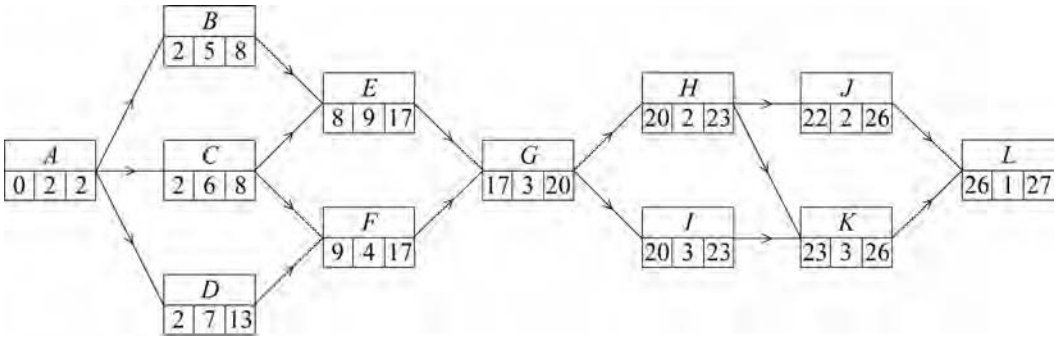
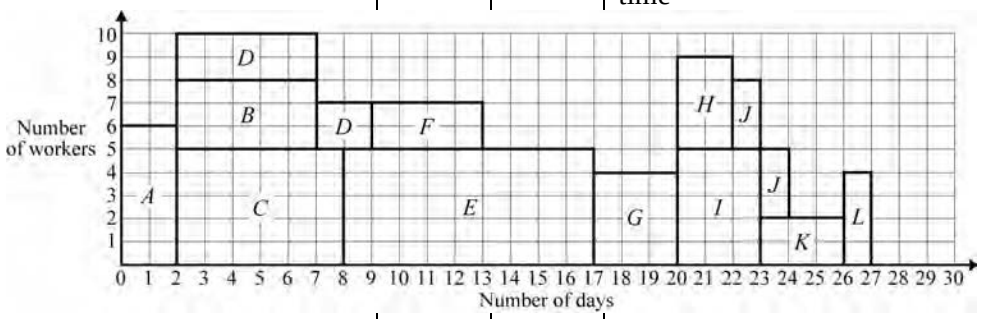
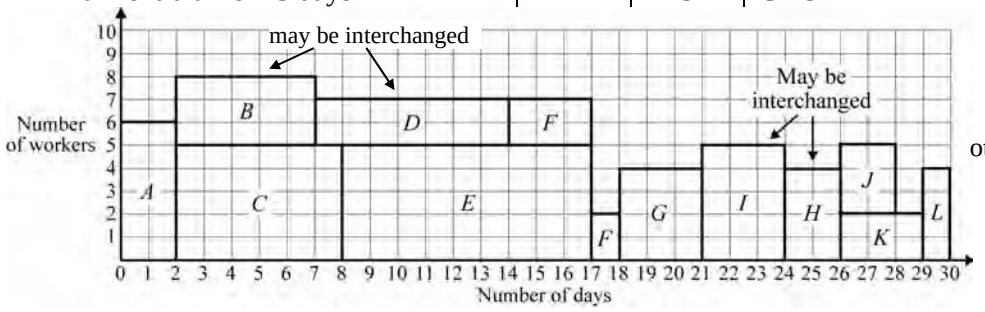
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

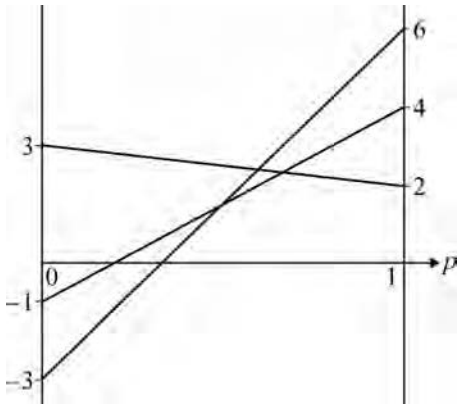
MD02

Q	Solution	Marks	Total	Comments
1				
(a)	Forward pass Correct Backward pass Correct	M1 A1 M1 A1	 4	up to one slip ft up to one slip ft
(b)(i)	Critical path *A C E G I K L*	B1		
(ii)	Float for *D* = 13 – 2 – 7 = 4 days	M1 A1	 3	'their 13' – 'their 2' – 7
(c)	*A C E G I K L* correct durations and heights *D* and *B* and *F* correct (no "holes") *H* and *J* correct (no "holes")	M1 A1 B1 B1	 4	one slip in duration or height correct withhold final mark earned if not clear which activities are taking place at any time
				
(d)	Correctly dealing with *D*, *B* and *F* Correctly dealing with *H* and *J* Minimum extra time = 3 days	B1 B1 B1	 3	ft 1 slip ft 1 slip CAO
	 other possibilities			
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)(i)	4 8 12 2 6 0 5 12 4 8 11 10 8 3 8 2 9 3 5 1 *n* *n* *n* *n* *n*	B1	1	
(ii)	No of rows = no of columns Hungarian algorithm minimises $20 - x$ gives measure of criteria not met which needs minimising	E1 E1 E1	3	square matrix by adding extra row (total score) points lost (in each entry)
(b)(i)	~~2~~ 6 10 ~~0~~ ~~4~~ ~~0~~ 5 12 ~~4~~ ~~8~~ ~~8~~ 7 5 ~~0~~ ~~5~~ ~~1~~ 8 2 ~~4~~ ~~0~~ ~~0~~ ~~0~~ ~~0~~ ~~0~~ ~~0~~	M1 A1√	 2	reducing rows column reduction leaves matrix unchanged ($p = 4$, $q = 5$) (ft one slip)
(ii)	Zeros covered with 4 lines shown	B1		row 5 and columns 1, 4 and 5
	~~2~~ 4 8 ~~0~~ 4 ~~0~~ 3 10 ~~4~~ 8 ~~8~~ 5 3 ~~0~~ 5 ~~1~~ ~~6~~ ~~0~~ ~~4~~ ~~0~~ ~~2~~ ~~0~~ ~~0~~ ~~2~~ ~~2~~	M1 A1		subtract 2 from all uncovered and add 2 to double covered (condone one slip) (follow through their p and q)
	2 1 5 (0) 1 (0) 0 7 4 5 8 2 (0) 0 2 4 6 0 7 (0) 5 (0) 0 5 2	M1 A1		augment (at least) one more time (condone one slip) may put line through second row and not first column M1 $\begin{matrix}0&2&6&0&2\\0&3&10&6&8\\6&3&1&0&3\\1&6&0&6&0\\2&0&0&4&2\end{matrix}$ → $\begin{matrix}0&1&5&0&1\\0&2&9&6&7\\6&2&0&0&2\\2&6&0&7&0\\3&0&0&5&2\end{matrix}$ A1 any correct final matrix requiring zeros to be covered by 5 lines
	1D, 2A, 3C, 4E is matching	B1	6	(field B unused)
(iii)	(18 + 20 + 12 + 19 =) 69	B1	1	
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)(i)	Row minima 2, –3, x	B1	1	} Check for answers written on table
(ii)	Column maxima 3, 6, 4	B1		
	Max (row min) = 2 Min (col max) = 3 Or $2 \neq 3$	M1		Condone Best (worst) =2 etc Worst (best) =3
	Since $2 \neq 3 \rightarrow$ no stable solution	A1cso	3	Both lines and statement must score previous B1, B1
(b)	$x < 2$, $x + 3 < 6$, $3 < 4$ $\rightarrow$ R_1 dominates R_3 } Either of these	B1	1	hence Rhona should not play R_3
(c)(i)	Let Rhona play R_1 with prob p and R_2 with prob $1 - p$			
	When C plays C_1: exp value $= 2p + 3(1-p)$			$= 3 - p$
	C_2: $6p - 3(1-p)$			$= -3 + 9p$
	C_3: $4p - (1-p) = -1 + 5p$	M1		any two correct unsimplified
		A1		all correct unsimplified
		M1		drawing two of their expected values for $0 \leq p \leq 1$ both vertical axes using same scale condone use of horizontal lines in paper
		A1		all three correct lines must see numbers on at least one vertical axis
	$3 - p = -1 + 5p$	M1		choosing highest point of region
	$\rightarrow p = \frac{2}{3}$	A1		
	$\rightarrow$ Rhona plays R_1 $\frac{2}{3}$ of time and R_2 $\frac{1}{3}$ of time	E1√	7	ft their p
(ii)	Value of game $= 3 - \frac{2}{3} = \frac{7}{3}$	B1	1	or $-1 + \frac{10}{3} = \frac{7}{3}$
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	$\frac{4}{-1} = -4;\ \frac{10}{2} = 5;\ \frac{21}{4} = 5\frac{1}{4}$ 5 is smallest **positive** ratio	E1		Must see 5 and $5\frac{1}{4}$ plus correct statement
	Pivot = 2	B1	2	
(ii)	$1\ \ 0\ \ -\frac{1}{2}\ \ 5\ \ 0\ \ \frac{3}{2}\ \ 0\ \ 15$	M1		row operations (even with wrong pivot)
	$0\ \ 0\ \ \frac{3}{2}\ \ 3\ \ 1\ \ \frac{1}{2}\ \ 0\ \ 9$	A1		1st, 2nd or last row correct
	$0\ \ 1\ \ \frac{1}{2}\ \ 2\ \ 0\ \ \frac{1}{2}\ \ 0\ \ 5$	A1		another of these correct
	$0\ \ 0\ \ 0\ \ -5\ \ 0\ \ -2\ \ 1\ \ 1$	A1		all correct (condone multiples of rows)
	Negative value in top row ($\rightarrow$ optimum not reached)	E1	5	must have negative value in their top row
(b)(i)	New pivot is 'their $\frac{3}{2}$' in y-column PI	M1		or multiple of this
	$1\ \ 0\ \ 0\ \ 6\ \ \frac{1}{3}\ \ \frac{5}{3}\ \ 0\ \ 18$	A1		1st, 3rd or 4th row correct
	$0\ \ 0\ \ 1\ \ 2\ \ \frac{2}{3}\ \ \frac{1}{3}\ \ 0\ \ 6$	A1		another of these rows correct
	$0\ \ 1\ \ 0\ \ 1\ \ -\frac{1}{3}\ \ \frac{1}{3}\ \ 0\ \ 2$			
	$0\ \ 0\ \ 0\ \ -5\ \ 0\ \ -2\ \ 1\ \ 1$	A1	4	all correct (condone multiples of rows)
(ii)	Optimum value of P reached	E1		must have no negative values in top row
	$P = 18$	B1√		ft their tableau
	$x = 2, y = 6, z = 0$	B1√		$s = 0, t = 0, u = 1$ (no more than 2 slips in final tableau for ft)
	$4x + 2y + 3z \leq 21$ still has slack	B1	4	Tableau must indicate u is only slack variable
	Total		**15**	

MD02 (cont)

<table>
<tr><th>Q</th><th>Solution</th><th>Marks</th><th>Total</th><th>Comments</th></tr>
<tr><td>5(a)</td><td>Completing stage 2 values (condone correct unsimplified) (all 7 values)

At least 6 values calculated at stage 3 (M0 for 10 or more values)
Using only their minimum F or G value from stage 2

All 9 stage 3 values correct

Using minima (at least 3) from A, B, C, D stage 3 in stage 4

All correct in stage 4</td><td>B1

M1

m1

A1

M1

A1</td><td>6</td><td>
<table>
<tr><th>Stage</th><th>State</th><th>From</th><th>Value</th><th></th></tr>
<tr><td>1</td><td>I</td><td>T</td><td>–7</td><td></td></tr>
<tr><td></td><td>J</td><td>T</td><td>–6</td><td></td></tr>
<tr><td></td><td>K</td><td>T</td><td>–5</td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>2</td><td>E</td><td>I</td><td>–7 – 4 = –11</td><td>←</td></tr>
<tr><td></td><td>F</td><td>I</td><td>–7 – 3 = –10</td><td>←</td></tr>
<tr><td></td><td></td><td>J</td><td>–6 – 2 = –8</td><td></td></tr>
<tr><td></td><td>G</td><td>I</td><td>–7 + 4 = –3</td><td></td></tr>
<tr><td></td><td></td><td>J</td><td>–6 + 7 = 1</td><td></td></tr>
<tr><td></td><td></td><td>K</td><td>–5 – 1 = –6</td><td>←</td></tr>
<tr><td></td><td>H</td><td>K</td><td>–5 + 4 = –1</td><td>←</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>3</td><td>A</td><td>E</td><td>–11 + 5 = –6</td><td></td></tr>
<tr><td></td><td></td><td>G</td><td>–6 – 2 = –8</td><td>←</td></tr>
<tr><td></td><td>B</td><td>E</td><td>–11 – 2 = –13</td><td></td></tr>
<tr><td></td><td></td><td>F</td><td>–10 – 4 = –14</td><td>←</td></tr>
<tr><td></td><td>C</td><td>F</td><td>–10 + 6 = –4</td><td></td></tr>
<tr><td></td><td></td><td>G</td><td>–6 – 3 = –9</td><td>←</td></tr>
<tr><td></td><td></td><td>H</td><td>–1 – 5 = –6</td><td></td></tr>
<tr><td></td><td>D</td><td>G</td><td>–6 – 5 = –11</td><td>←</td></tr>
<tr><td></td><td></td><td>H</td><td>–1 – 3 = –4</td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>4</td><td>S</td><td>A</td><td>–8 + 23 = 15</td><td></td></tr>
<tr><td></td><td></td><td>B</td><td>–14 + 28 = 14</td><td>←</td></tr>
<tr><td></td><td></td><td>C</td><td>–9 + 25 = 16</td><td></td></tr>
<tr><td></td><td></td><td>D</td><td>–11 + 25 = 14</td><td>←</td></tr>
</table>
</td></tr>
<tr><td>(b)</td><td>Minimum cost of ticket (£)14

Path S B F I T
S D G K T</td><td>B1√

B1
B1</td><td>3</td><td>ft their lowest stage 4 value

one correct path
2nd correct path and no others</td></tr>
<tr><td></td><td>Total</td><td></td><td>9</td><td></td></tr>
</table>

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	$SP \geq 12$ $SQ \geq 10$ $SR \geq 17$ $YT \geq 18$ $ZT \geq 17$	B1 B1	 2	S in correct place, (arrows) and capacities T in correct place, (arrows) and capacities
(b)	$S\ P\ U\ Y\ T$ 10 $S\ R\ V\ W\ Z\ T$ 8	B1 B1	 2	
(c)(i)	Initial flow forward and backward PU 2 and 10 ; UY 0 and 10 RV 0 and 8 ; VW 1 and 8 ; WZ 2 and 8	 B1 B1	 2	 withhold one B1 if paths to S and T not updated
(ii)	Two correct routes and flows on Figure 6 Correct additional flows Max flow = 33 Adjustment of at least 4 edges corresponding to flows (forward and backward) Correct final flows forward and backward (must score A1 for table)	M1 A1 M1 A1cso	 4	$S\ P\ U\ Y\ T$ 10 $S\ R\ Y\ W\ Z\ T$ 8 $S\ P\ U\ X\ Y\ T$ 2 $S\ Q\ V\ U\ X\ Y\ T$ 6 $S\ R\ W\ X\ Z\ T$ 5 $S\ R\ W\ Z\ T$ 2 (other possibilities) edges UY, UX, WX and WZ will be saturated $XY + XZ = 13$ in back flow
(d)	Cut with value 33 is through UY, UX, WX and WZ	B1	1	
	Total		**11**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education (A-level)
June 2011

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 candidates' 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 candidates' 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.

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.

Further copies of this Mark Scheme are available from: aqa.org.uk

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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.

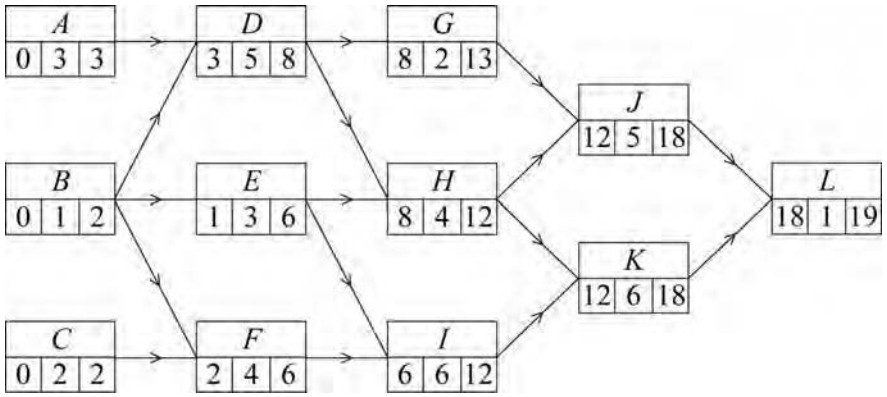
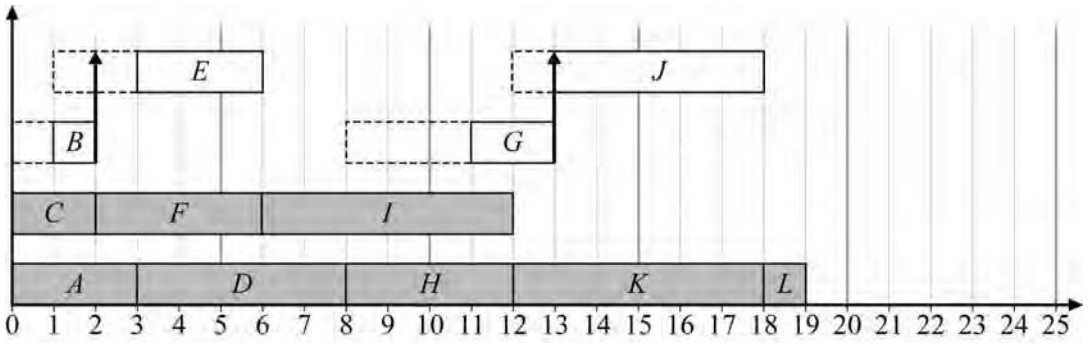
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

MD02

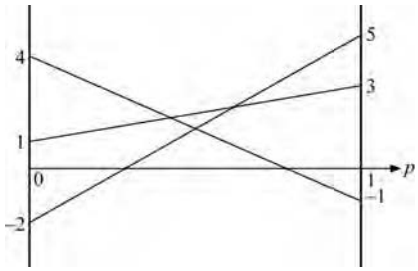
Q	Solution	Marks	Total	Comments
1(a)				
	Earliest start times	M1 A1		condone one slip + ft all correct
	Latest finish times	M1 A1	4	condone one slip + ft all correct
(b)	Critical paths *A D H K L* *C F I K L* Minimum time = 19	B1 B1 B1	3	one path correct second path correct and no others 19 days
(c)	Greatest float time at *G* $(13-8-2)=3$ (days)	M1 A1cso	2	ft their activity with greatest float for M1 values at *G* must be correct
(d)	*A, D, H, K, L* and *C, F, I* *B, E, G, J* *B(1-2); E(3-6); G(11-13); J(13-18)*	M1 A1 M1 A1cso	4	one of 'their' critical paths "correct" all 8 of these activities correct 3 of these with correct duration and latest start time (may omit slack) all 4 correct with correct slack shown
				
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	3 1 0 4 1 1 4 1 2 4 1 0 3 1 2 2 3 2 0 0 0 5 1 2 1	M1		reducing columns first
	3 1 0 4 1 0 *k* 0 1 3 1 0 3 1 2 2 3 2 0 0 0 5 1 2 1	A1cso	2	then rows *k* = 3 stated or value 3 in table **AG**
(b)(i)	Lines through columns 1, 2, 3 and row 4	B1	1	
(ii)	3 1 0 3 0 0 3 0 0 2 1 0 3 0 1 3 4 3 0 0 0 5 1 1 0	M1 A1	2	subtract 1 from all uncovered and add 1 to all double covered (condone one slip) all correct ISW
	This now requires 5 lines to cover zeros			
(c)	*A*2 *B3* *C1* *D4* *E5*	B1		one of these correct
	A5 *B3* *C1* *D2* *E4*	B1		second way correct
	*A*5 *B3* *C*2 *D4* *E1*	B1	3	third way correct and no others
(d)	Minimum total = 68 (mins)	B1	1	
(e)	Replace each element x by $N - x$	E1	1	any value of N
	Total		**10**	

Q	Solution	Marks	Total	Comments
3(a)	Row minima are $-4, -3, -7$	M1		**both** row minima **and** column maxima attempted (condone 2 errors)
	Column maxima are $-3,\ 6,\ 8$	A1		all values correct
	max (row min) = min (col max) $= -3$	E1		condone arrows pointing to this element but must **state** max (row min) and min (col max) or equivalent
	Play-safe Tom **II** and Jerry **A**	B1	4	

MD02 (cont)

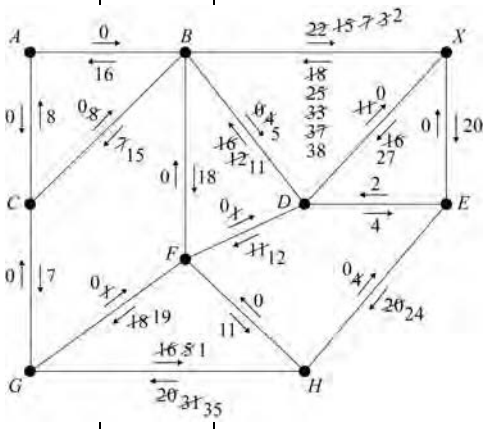
Q	Solution	Marks	Total	Comments
3(b)(i)	Let Rohan play R_1 with prob p $\Rightarrow$ plays R_2 with prob $1-p$			
	When Carla plays C_1, Rohan's expected gain $= 3p + (1-p)$ $= 1 + 2p$			
	$C_2 : 5p + (-2)(1-p) = 7p - 2$	M1		at least 2 expected gains correct unsimplified
	$C_3 : -p + 4(1-p) = 4 - 5p$	A1		all 3 correct unsimplified
		M1		at least 2 lines correct
		A1		all lines correct for $0 \leqslant p \leqslant 1$ and values at 0 and 1 clear
				choosing highest point
	$7p - 2 = 4 - 5p$ $12p = 6$	M1		or using correct equation
	$\Rightarrow p = \frac{1}{2}$ $\Rightarrow$ Rohan plays R_1 50% of the time and R_2 50% of the time	A1cso		
	Value of game $= 7 \times \frac{1}{2} - 2 = \frac{3}{2}$ AG	B1	7	or $4 - \frac{5}{2} = \frac{3}{2}$ must see working
(b)(ii)	When Rohan plays R_1, expected loss for Carla is $3p + 5q + (-1)(1-p-q)$			
	and when Rohan plays R_2, expected loss for Carla is $p + (-2)q + 4(1-p-q)$	M1		either expression correct unsimplified
	$4p + 6q = \frac{3}{2} + 1$ $3p + 6q = 4 - \frac{3}{2}$	A1		correct simultaneous equations unsimplified
	$\Rightarrow p = 0,\ q = \frac{5}{12}$	A1		condone 0.42 or better
	$\Rightarrow$ Carla never plays C_1, plays C_2 with prob $\frac{5}{12}$ and plays C_3 with prob $\frac{7}{12}$	E1cso	4	Must have all 3 correct probabilities
	Total		**15**	

MD02 (cont)

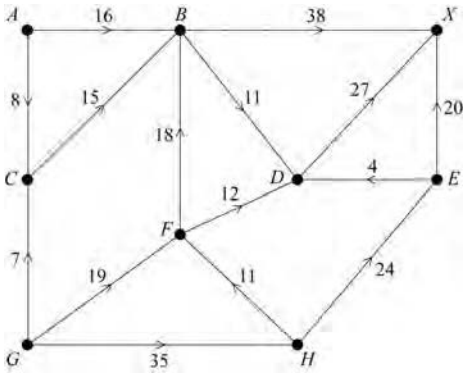
Q	Solution	Marks	Total	Comments
4(a)	$5x+3y+10z \leqslant 15$ $7x+6y+4z \leqslant 28$ $4x+3y+6z \leqslant 12$	M1 A1	 2	2 inequalities correct or all 3 LHS & RHS correct but using $<$ all correct
(b)(i)	Choosing 3 from bottom row as pivot	B1		identified or used
	$\begin{array}{cccccccc} 1 & 6 & 0 & 12-k & 0 & 0 & 2 & 24 \\ 0 & 1 & 0 & 4 & 1 & 0 & -1 & 3 \end{array}$	M1		row operations (even with wrong pivot)
	$0 \quad -1 \quad 0 \quad -8 \quad 0 \quad 1 \quad -2 \quad 4$	A1		one of rows 1, 2, 3 correct
	$0 \quad \frac{4}{3} \quad 1 \quad 2 \quad 0 \quad 0 \quad \frac{1}{3} \quad 4$	A1	4	all correct (condone multiples of rows)
(ii)	$12-k<0$ $\Rightarrow k>12$	M1 A1	 2	their '$12-k$' <0 SC B1 for $k \geqslant 13$
(c)(i)	$\begin{array}{cccccccc} 1 & 6 & 0 & -8 & 0 & 0 & 2 & 24 \\ 0 & 1 & 0 & 4^* & 1 & 0 & -1 & 3 \\ 0 & -1 & 0 & -8 & 0 & 1 & -2 & 4 \\ 0 & \frac{4}{3} & 1 & 2 & 0 & 0 & \frac{1}{3} & 4 \end{array}$	M1		correct pivot from z column 4* (identified or used)
	$\begin{array}{cccccccc} 1 & 8 & 0 & 0 & 2 & 0 & 0 & 30 \\ 0 & \frac{1}{4} & 0 & 1 & \frac{1}{4} & 0 & -\frac{1}{4} & \frac{3}{4} \\ 0 & 1 & 0 & 0 & 2 & 1 & -4 & 10 \\ 0 & \frac{5}{6} & 1 & 0 & -\frac{1}{2} & 0 & \frac{5}{6} & \frac{5}{2} \end{array}$	A1 A1 A1	 4	one of rows 1, 3 or 4 correct another of rows 1, 3 or 4 correct all correct (condone multiples of rows)
(ii)	Maximum value of P now reached	E1		their tableau must have no negatives in top row
	$P=30,\ x=0,\ y=\frac{5}{2},\ z=\frac{3}{4}$	B1√		ft their values from their tableau provided at least 2 marks earned in (c)(i)
	$s=0,\ t=10,\ u=0$	B1cao	3	condone up to 2 slips in their final tableau
	Total		**15**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)	Cut value $= 40 + 27 + 0 + 24$ $= 91$	B1	1	
(b)	*ABDX* 16 *GFBX* 18 *GHEX* 20	B1 B1 B1	3	
(c)(i)	One correct route with additional flow	M1		any feasible route and flow
	Another 2 routes and flows correct	A1		total flow at least 80
	All routes correct with total flow = 85	A1cso		
	Forward and backward flows on diagram (directions must be clear)	M1		at least 8 edges with pairs of values 'correct'
	Augmenting flows	A1cso	5	correct
	Consider other possible correct flows *Condone diagram as shown but really should have initial flows in DE, etc*			
(ii)	Max flow = 85	B1		
	Correct max flow	B1	2	
	Consider other possible correct flows			
(d)	Considering 'their' *AB*+*CB*+*FB* – 45 = 4 fewer ⇒ max number = 81	M1 A1cao	2	
	Total		**13**	



Route	Flow
ABDX	16
GFBX	18
GHEX	20
GCBX	7
ACBX	8
GHFDX	11
GHEDBX	4
GFDBX	1



MD02 (cont)

Q	Solution	Marks	Total	Comments
6	Wednesday profits	M1		4 more calculations/ profits correct
		A1		6 more profits correct
		A1		all profits correct
	Tuesday: use of maxima from Wednesday	M1		6 more calculations/profits correct
		A1		8 profits correct
		A1√		all profits correct ft one slip from Wednesday figures
	Monday values correct	A1√		all profits correct ft one slip from Tuesday figures
	(Monday builds shed) *D*	M1		Choosing largest Monday profit from their table
	⇒ order *D B A C*	A1cso	9	SC B1 only for order *D B A C* NMS or without "correct" table

Stage (Day)	State (Sheds already built)	Action (shed to build)	Calculation	Profit in pounds	
Thursday	*A, B, C*	*D*		90	
	A, B, D	*C*		87	
	A, C, D	*B*		76	
	B, C, D	*A*		70	
Wednesday	*A, B*	*C*	84 + 90	174	
		D	88 + 87	175	→
	A, C	*B*	71 + 90	161	→
		D	82 + 76	158	
	A, D	*B*	74 + 87	161	→
		C	83 + 76	159	
	B, C	*A*	65 + 90	155	
		D	86 + 70	156	→
	B, D	*A*	69 + 87	156	→
		C	85 + 70	155	
	C, D	*A*	66 + 76	142	
		B	73 + 70	143	→
Tuesday	*A*	*B*	72 + 175	247	→
		C	83 + 161	244	
		D	84 + 161	245	
	B	*A*	60 + 175	235	
		C	80 + 156	236	
		D	83 + 156	239	→
	C	*A*	57 + 161	218	
		B	68 + 156	224	
		D	85 + 143	228	→
	D	*A*	62 + 161	223	
		B	70 + 156	226	→
		C	81 + 143	224	
Monday	-	*A*	50 + 247	297	
		B	65 + 239	304	
		C	70 + 228	298	
		D	80 + 226	306	→

Schedule

	Monday	Tuesday	Wednesday	Thursday
Shed to build	*D*	*B*	*A*	*C*

	Total		**9**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education (A-level)
January 2012

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.

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

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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.

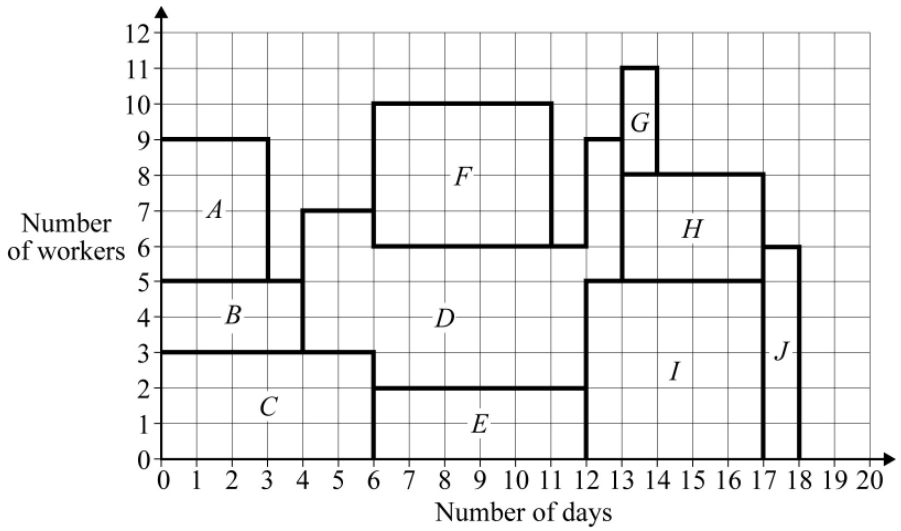
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

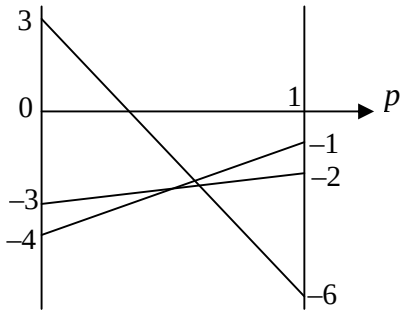
MD02

Q	Solution	Marks	Total	Comments
1(a)	$x = 4$ $y = 12$ $z = 13$	B1 B1 B1	3	
(b)	*B D H J* and *C E I J*	M1 A1	2	first correct path 2nd correct and no others
(c)	*G* Float = 3	B1 B1	2	
(d)	One of their CPs correct height *B, D, H, J* and *C, E, I* correct	M1 A1		and correct durations and correct durations
				
	A starting at 0 and ending at 3 *F* starting at 6 and ending at 11 *G* starting at 13 and ending at 14	M1 A1 A1	5	one correct with correct height two correct with correct height all correct with correct height withhold first A1 earned if it is not clear which activities take place at any given time withhold another A1 if "holes" appear in histogram
(e)	New earliest *J* 22 days	B1		assuming activities continuous
	Minimum extra time 5 days	B1	2	assuming activities continuous
	Total		**14**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
2(a)	Hungarian algorithm used to find **minimum total** **Each new entry** gives measure of points **not** scored $\Rightarrow$ Hungarian algorithm now finds maximum total score	E1 E1	2	First E1– fairly generous for idea of "minimising" or "points not scored". Second E1 is strict.
(b)	Replacing x by $35 - x$			
	8 6 10 0 4 2 13 18 6 6 12 6 10 2 14 13 6 6 8 4 8 8 16 14 8	B1		Must see this table
	8 6 10 0 4 0 11 16 4 4 10 4 8 0 12 9 2 2 4 0 0 0 8 6 0	M1		reducing rows; ft one slip from above & allow one further slip
	8 6 8 0 4 0 11 14 4 4 10 4 6 0 12 9 2 0 4 0 0 0 6 6 0	A1cso	3	check working is correct since most values in final table are given. ($p = 14$ $q = 9$)
(c)	Lines covering R_4 , R_5 and C_1 , C_4	B1		4 correct lines
	8 2 4 0 0 0 7 10 4 0 10 0 2 0 8 13 2 0 8 0 4 0 6 10 0	M1 A1	3	subtracting 4 from each uncovered and adding 4 to each double covered (condone 2 slips) all correct
(d)(i)	B1 and D3 A4 B1 C2 D3 E5 A5 B1 C4 D3 E2	M1 A1 A1	3	or one **full** matching with rings etc one correct matching second correct and no others
(ii)	Total = 153	B1	1	
	Total		**12**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
3(a)	**For each pair of strategies** Roz gain + Colum gain = 0	E2,1	2	E1 for general idea of Roz gain + Colum gain = 0
(b)	Colum's max are $-2, 3, -1$			must see these values for E1
	min (colum max) = –2	E1		
	$\Rightarrow$ play safe is C_1	B1	2	
(c)(i)	Delete R_2 (PI by further work)	M1		C_1 C_2 C_3 -2 -6 -1 R_1
	Since R_3 dominates R_2	A1	2	-3 3 -4 R_3
(ii)	Let Roz play R_1 with prob p			
	C_1 expected gain: $-2p-3(1-p)=p-3$			
	$C_2: -6p+3(1-p)=3-9p$	M1		2 expressions unsimplified ft their matrix
	$C_3: -p-4(1-p)=3p-4$	A1		all correct
		M1		plotting 3 expected gains for $0 \leqslant p \leqslant 1$
		A1		correct gains plotted accurately
	Solving $p-3=3-9p$	m1		choosing highest point of 'their' region or correct pair solved
	$\Rightarrow 10p=6$			
	$p=\frac{3}{5}$	A1		
	$\Rightarrow$ Roz plays R_1 with probability $\frac{3}{5}$ and R_3 with probability $\frac{2}{5}$	E1cao	7	must see R_1 and R_3
	Total		**13**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
4(a)(i)	x-column pivot = 6 $\frac{2}{2}=1$, $\frac{3}{6}=\frac{1}{2}$ $\left(\text{and } \frac{1}{2}<1\right)$ smallest **positive** quotient	B1 B1 E1	3	need to see correct quotients considered negative value **must** be mentioned as being considered but rejected
(ii)	***P*** ***x*** ***y*** ***z*** ***s*** ***t*** ***u*** **value** 1 0 1 0 1 $\frac{1}{3}$ 0 7 0 0 13 1 3 $-\frac{1}{3}$ 0 1 0 1 –5 0 –1 $\frac{1}{6}$ 0 $\frac{1}{2}$ 0 0 –14 0 –4 $\frac{1}{6}$ 1 $4\frac{1}{2}$	M1 A1 A1 A1	4	row operations 1st, 2nd or 4th row correct another of these 3 correct all correct (condone multiples of rows)
(b)(i)	No negatives in **top row**	E1	1	**but** must have no negative values in "their" top row
(ii)	One (inequality still has slack)	B1	1	
(c)(i)	$P = 7$ $x=\frac{1}{2}$, $y=0$, $z=1$	B1√ B1 cao	2	FT their tableau condone one slip in final tableau
(ii)	Substituting "their" values from (c) (i) $\frac{1}{2}k + 0 + 3 = 7$ $\Rightarrow k = 8$	 M1 A1	2	
			13	

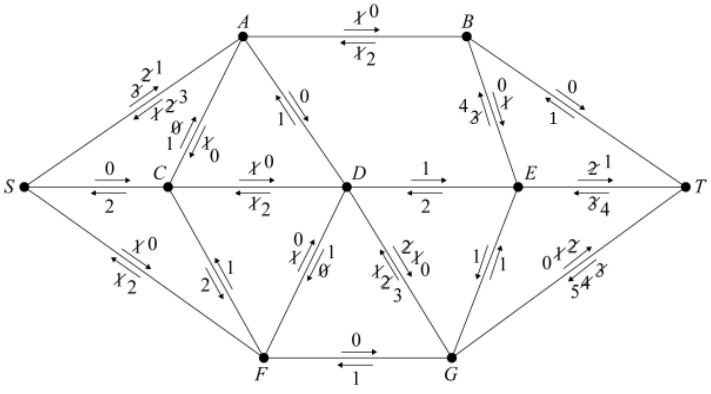
MD02 (cont)

Q	Solution	Marks	Total	Comments
5(a)				

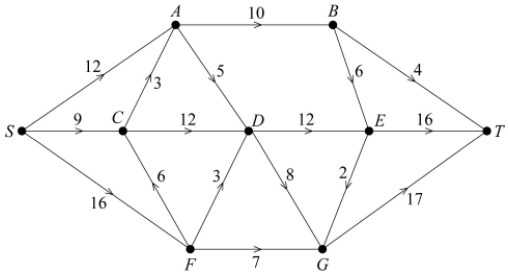
Stage	State	From	Calculation	
1	G	T		15
	H	T		17
	I	T		26
2	D	G	6 + 15	21 ←
		H	3 + 17	20
	E	G	–3 + 15	12
		H	–6 + 17	11
		I	–13 + 26	13 ←
	F	H	–7 + 17	10
		I	–14 + 26	12 ←
3	A	D	–4 + 21	17
		E	6 + 13	19 ←
	B	D	12 + 21	33 ←
		E	16 + 13	29
		F	18 + 12	30
	C	E	14 + 13	27 ←
		F	13 + 12	25
4	S	A	12 + 19	31*
		B	–2 + 33	31*
		C	3 + 27	30

Q	Solution	Marks	Total	Comments
		B1		stage 1 correct
		M1		7 values at stage 2 attempted with 5 unsimplified calculations correct
		A1		stage 2 correct
		M1		use of two of "their" maxima from Stage 2 to Stage 3
		A1		stage 3 correct
		A1cso	6	stage 4 & all other values correct
(b)	Maximum profit = 31	B1√		£31 million
	$SAEIT$ and $SBDGT$	B1 B1	3	one correct path second correct path and no other
	Total		**9**	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(a)	$10 + 13 - 1 + 17$ $= 39$	M1 A1	2	3 values added and –1 (condone one slip)
(b)(i)	*DE* 12 *FG* 7	B1 B1	2	on Figure 2
(ii)	**arc** **forward** **backward** *SA* 3 1 *AB* 1 1 *BT* 0 1 *SC* 0 2 *CA* 0 1 *AD* 0 1 *CD* 1 1 *DE* 1 2 *BE* 1 3 *ET* 2 3 *SF* 1 1 *FC* 1 2 *FD* 1 0 *FG* 0 1 *DG* 2 1 *EG* 1 1 *GT* 2 3	M1 A1	 2	at least 6 pairs correct on Figure 3 (must have arrows) all correct
(iii)	**Table** **Path** **Extra Flow** *SABET* 1 *SFDGT* 1 *SACDGT* 1	M1 A1		1 correct path and extra flow all correct *DEG triangle may have different flows with implications to triangle GET.*
	Network  	M1 A1	 4	1 path correctly augmented forward and backward **bu**t must have earned M1 in part (b)(ii) network correct
(c)(i)	Max flow = 37	B1	1	

MD02 (cont)

Q	Solution	Marks	Total	Comments
6(c) cont.				
(ii)	Max flow 	B2	2	correct flow of 37 condone 2 slips or omissions in flow of 37 **or** "correct" feasible flow of 36 for SC1
(d)	Cut through *AB*, *AD*, *CD*, *FD* and *FG*	B1	1	$\{ S, A, C, F \}$ $\{ B, D, E, G, T \}$
	Total		**14**	
	TOTAL		**75**	

Version

General Certificate of Education (A-level)
June 2012

Mathematics MD02

(Specification 6360)

Decision 2

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.

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

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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.

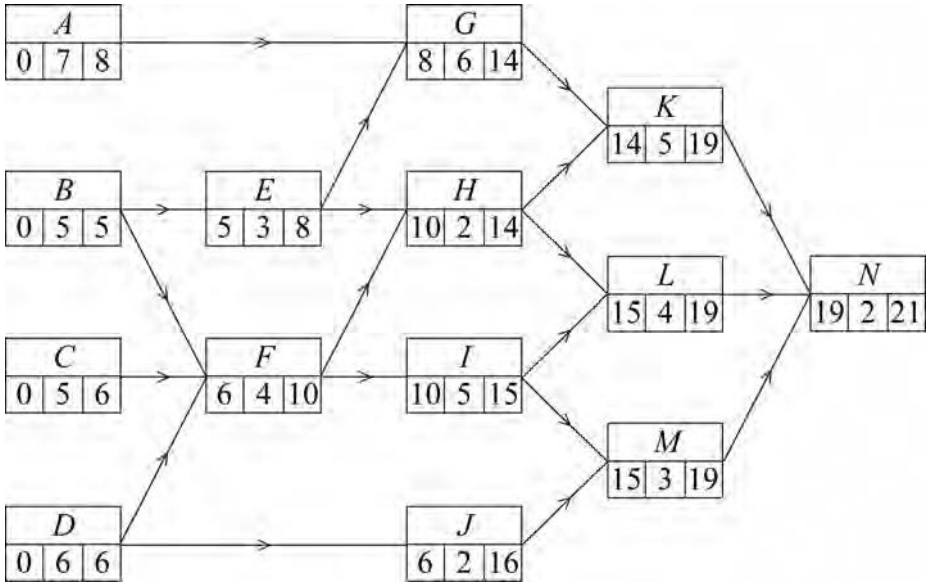
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

MD02

Q	Solution	Marks	Total	Comments
1(a)				
	Forward pass	M1 A1		condone one slip (follow through) all correct
	Backward pass	M1 A1	4	condone one slip (follow through) all correct
(b)	Critical paths $B\ E\ G\ K\ N$ $D\ F\ I\ L\ N$	M1 A1		first path correct second path and no others
	Minimum completion time is 21 days	B1	3	
(c)	Cascade diagram			may be in blocks or bars (see examples)
	One of 'their' CPs correct	M1		ft their CP
	B , D , E , F , G , I , K , L , N	A1		these activities correct
	A , C , H , J , M	M1 A1 A1	5	3 of these with correct start and duration 3 correct with correct slack indicated all 5 correct with correct slack
				Slack A 0 – 7 7 – 8 C 0 – 5 5 – 6 H 10 – 12 12 – 14 J 6 – 8 8 – 16 M 15 – 18 18 – 19
(d)	(Max value of x is) 10	M1		considering $J_{\text{latest}} - J_{\text{earliest}}$
	$\Rightarrow x \leqslant 10$	A1 cao	2	(condone $x < 11$ for SC2) NMS $x \leqslant 10$ award M1 A1
	Total		**14**	

MD02

Q	Solution	Marks	Total	Comments
2(a)	0 1 2 4 3 ** 3 3 ** 0 1 4 4 2 0 0 0 2 0 0 0 3 2 0 0	M1		*may have large number instead of ** throughout this question* row adjustment (condone one slip) identical numerical error in more than one term is one slip
	0 1 0 4 3 ** 3 1 ** 0 1 4 2 2 0 0 0 0 0 0 0 3 0 0 0	A1 B1	 3	then columns four lines through rows 1, 4 & 5 and column 5 *ft one slip from above for next two marks*
(b)	adjustment adding 1 to double covered and – 1 to uncovered 0 1 0 4 4 ** 2 0 ** 0 0 3 1 1 0 0 0 0 0 1 0 3 0 0 1	M1 A1√ A1	 3	ft 'their lines and table' provided no more than one slip in earlier table must make $\leqslant 2$ further errors for M1 ($\leqslant 1$ further error in adjustment) correct
(c)	B4 and D5 allocated A1 B4 C2 D5 E3 A3 B4 C1 D5 E2	M1 A1 A1	 3	(or one complete matching ringed) one correct allocation 2nd matching and no others 1A 2C 3E 4B 5D 1C 2E 3A 4B 5D
(d)	13 + 16 + 21 + 20 + 15 } or 16 + 16 + 15 + 20 + 18 } Min Total Time = 85 (min)	 B1	 1	
	Total		**10**	

MD02

Q	Solution	Marks	Total	Comments
3(a)	P x y z s t value 1 $-k$ -6 -5 0 0 0			*may have 1's in 's' and 't' columns interchanged*
	0 2 1 4 1 0 11	B1		second row correct
	0 1 (3) 6 0 1 18	B1	2	third row correct
				may earn next B1 M1 if no slack variables
(b)		B1		pivot is 3 (identified or used)
	1 $2-k$ 0 7 0 2 36 0 $\frac{5}{3}$ 0 2 1 $-\frac{1}{3}$ 5 0 $\frac{1}{3}$ 1 2 0 $\frac{1}{3}$ 6	M1		row operations (even with wrong pivot) (obtaining 0 in pivot column)
		A1		first or second row correct
		A1	4	all correct (condone multiples of rows)
(c)(i)	($k = 1 \Rightarrow$ max reached) since there are no negative values in top row	E1		provided there are no negative values in top row " all positive values... " scores E0
	(P_{max} =) 36	B1√	2	ft their tableau
(ii)	$k = 3$: new pivot from x-column is $\frac{5}{3}$ used by attempting row operation	M1		ft their pivot if appropriate but must have slack variables
	1 0 0 $\frac{41}{5}$ $\frac{3}{5}$ $\frac{9}{5}$ 39 0 1 0 $\frac{6}{5}$ $\frac{3}{5}$ $-\frac{1}{5}$ 3 0 0 1 $\frac{8}{5}$ $-\frac{1}{5}$ $\frac{2}{5}$ 5	A1 √		first or last row correct ft one slip from their tableau in part (b) but must use correct pivot
		A1	3	all correct (condone multiples of rows)
	Optimum reached (or P_{max} = ...)	E1		must have earned M1 and have no negative values in top row
	39	B1√		ft their tableau
	$x = 3$, $y = 5$, $z = 0$ ($s = 0$, $t = 0$)	B1 cso	3	must have correct final tableau
	Total		**14**	

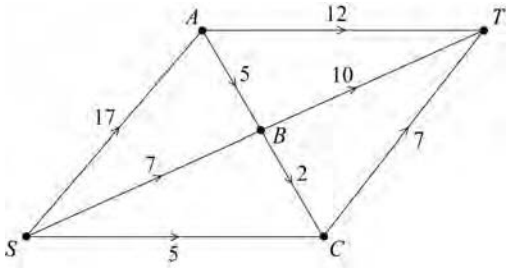
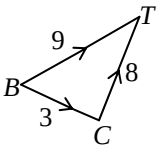
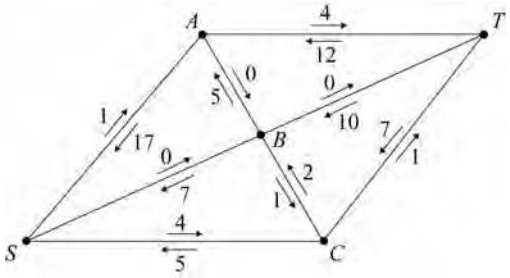
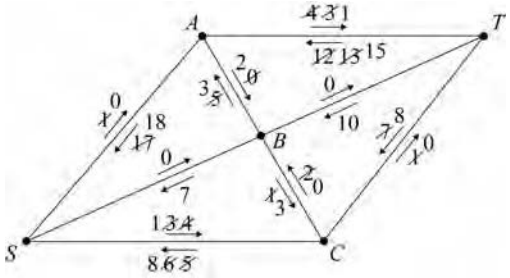
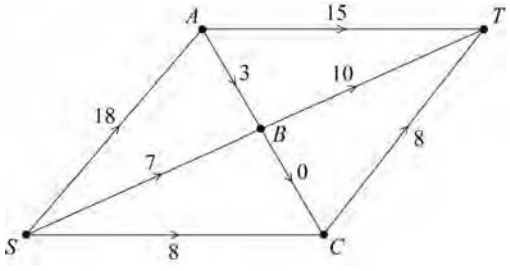
MD02

Q	Solution	Marks	Total	Comments
4(a)(i)	Row min $-6,\ -3,\ -5,\ -4$ Max (row min) = -3	M1		attempt to find maximin and minimax condone one slip in values
	Col max $5,\ 4,\ -3$ Min (col max) = -3	A1		**all** rows min and col max **values correct** **and** max (row min) = -3 **identified** **and** min (col max) = -3 **identified**
	max (row min) = min (col max) = -3 $\Rightarrow$ game has a stable solution	E1	3	**full** statement involving maximin and minimax **and** both values = -3
(ii)	Adam plays $\mathbf{A_2}$ & Bill plays $\mathbf{B_3}$	B1	1	
(iii)	Value of game for Bill is +3	B1	1	***Examiners must use the correct symbol for marks carried forward at the bottom of page 9 and top of page 10, ie ringed totals with arrows through them.***
(b)(i)	(Never play) $\mathbf{C_2}$ C_2 dominated **by** C_1 ($-3 > -4$ and $2 > 1$)	B1	1	correct strategy stated **and** correct reason condone $3 < 4$ and $-2 < -1$
(ii)	C_1 : $3p - 2(1-p)$ C_3 : $-3p + 5(1-p)$	M1 A1	2	either correct unsimplified both correct unsimplified $\{5p-2,\ 5-8p\}$
(iii)	$3p - 2(1-p) = -3p + 5(1-p)$ $\Rightarrow \quad p = \frac{7}{13}$	M1 A1	2	equating their 2 expressions
(iv)	Value of game $= 5\times\frac{7}{13} - 2$ $= \frac{9}{13}$	B1	1	or $5 - 8\times\frac{7}{13}$
	Total		**11**	

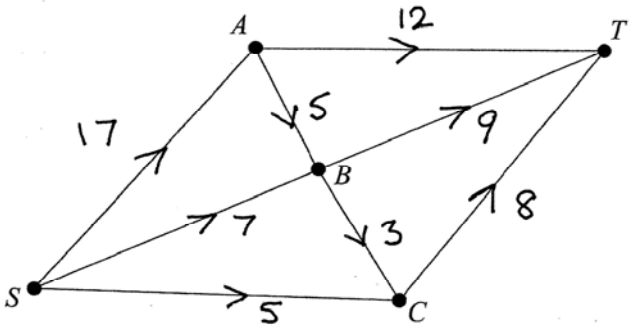
MD02

Q	Solution	Marks	Total	Comments
5(a)(i)	(*BAC* : 70 , 55 , 75) Least annual cost = 55	B1		£55 000
(ii)	*ABC* (involves costs 60 , 75 , 75) Least annual cost = 60	B1		£60 000
	ABC is better, since 60 > 55	E1	3	statement & reason with both least annual costs correct
(b)	**Year 3** 75 , 80 , 60			
	Year 2 Calc Value min (75 , 75) 75 ← min (70 , 80) 70	M1		Finding minima for 4 of "their" pairs in Year 2
	min (55 , 75) 55 min (60 , 60) 60 ←	A1		4 correct comparisons seen in Year 2
	min (65 , 80) 65 ← min (80 , 60) 60	A1		all values correct **and** comparison figures shown and correct for Years 2 and 3
	Year 1 *A* min (60 , 75) 60	m1		choosing all "their" maxima from Year 2 and all "their" comparisons correct
	B min (70 , 60) 60 *C* min (65 , 65) 65 ←	A1cso		all correct and word "**minimum"** seen in working – (condone "min" seen once)
	Optimum order is ***CAB***	M1		order starting with their **maximum** value from **Year 1** in table **BUT** maximin must have been attempted
		A1cso	7	correct order; allow this A1cso if only error in table is omission of word "minimum" **SC** B1 for *CAB* if no evidence of maximin from table (or network).
	Total		**10**	

MD02

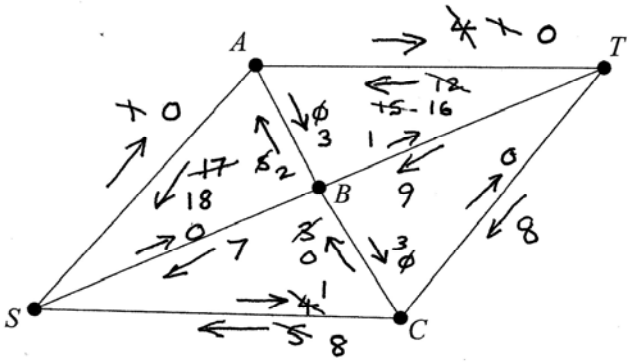
Q	Solution	Marks	Total	Comments
6(a)(i)	18 +(0+) 10 + 3 + 5 (= 36)	B1	1	
(ii)	30 , 32 , 36 (missing cut values)	B3	3	B1 each value correct
(iii)	Max flow = 29	B1		Award B0 E1 if their min^{m} cut is < 29
	because value of minimum cut is 29	E1	2	and min^{m} value explained as max flow
(iv)		B1 cao	1	may have  see alternative solution on next page
(b)(i)		M1		potential flow (forward and back) 4 pairs 'correct' including *SC* and *AT* ft their (a)(iv) provided 0 < flow < 30
		A1√		all pairs correct (condone missing 0s) ft their (a)(iv) if correct flow < 29
		m1		one correct flow in table
		A1		table correct *SAT* 1 *SCT* 1 *SCBAT* 2 If (a)(iv) flow < 29 then may score A1 for correct table giving max flow of 33
				(see also the alternative solution)
		m1		modifying flows (forward and back) 1 flow correct ft their initial flow
		A1	6	modified flows all correct, including all 0s (may score A1 from a correct flow < 29 seen in (a)(iv) if final flow correct)
(ii)	new max flow = 33	B1		
		M1		6 flows correctly interpreted from their labelling procedure provided M2 or M3 scored in (b)(i) *(may have AB 2, AT 16, BT 9 – see over)*
		A1	3	flow correct **SC** B1 if flow of 33 shown correctly but not from correct labelling procedure
	Total		**16**	
	TOTAL		**75**	

(iv) Indicate on the diagram below a possible flow along each edge corresponding to this maximum flow. *(1 mark)*



(b) The capacities along SC and along AT are each increased by 4 litres per second.

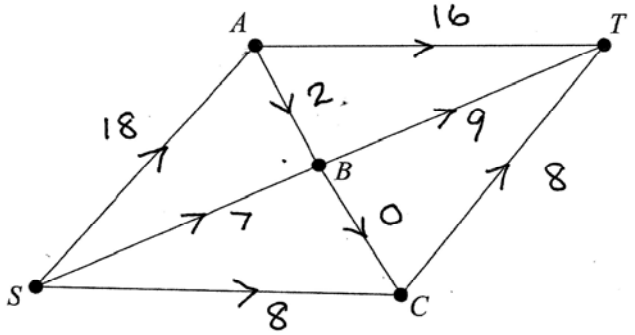
(i) Using your **values from part (a)(iv) as the initial flow**, indicate potential increases and decreases on the diagram below and use the labelling procedure to find the new maximum flow through the network. You should indicate any flow augmenting paths in the table and modify the potential increases and decreases of the flow on the diagram. *(6 marks)*



Path	Additional Flow
SCBAT	3
SAT	1

(ii) Use your results from part **(b)(i)** to illustrate the flow along each edge that gives this new maximum flow, and state the value of the new maximum flow. *(3 marks)*

New maximum flow is ..... 33 litres per second .....



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.

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

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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

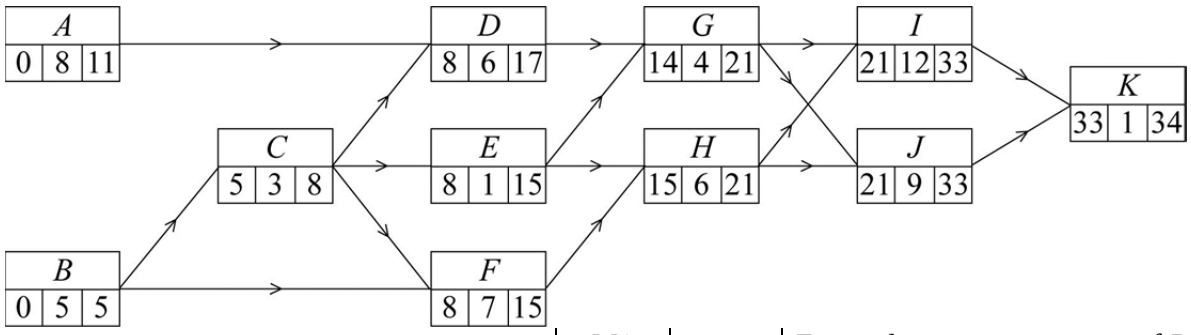
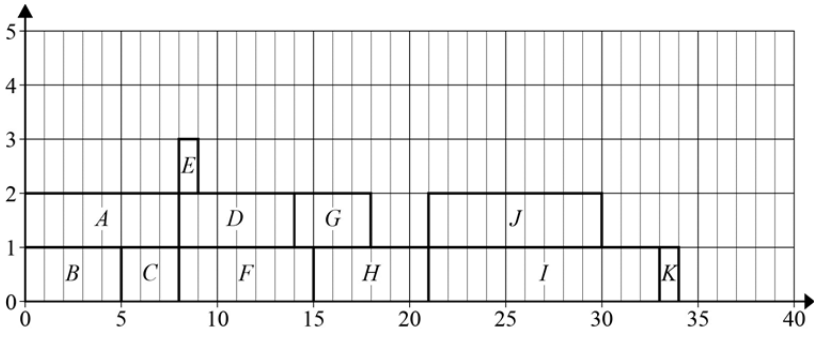
Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

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**.

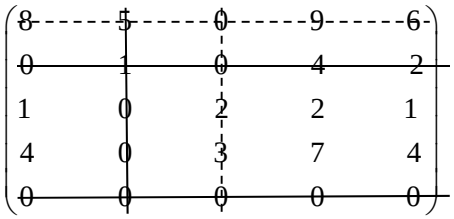
Otherwise we require evidence of a correct method for any marks to be awarded.

Q	Solution	Marks	Total	Comments
1(a)		M1		Forward pass, correct at two of *D*, *E*, *F*
		A1		All correct
		M1		Backward pass, correct at *G* **AND** *H* ft
		A1	4	All correct
(b)	**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		6+ correct
		B1	2	All correct
(c)	(Critical) *B C F H I K*	B1	1	
(d)	(Float *E)* 6 (hrs)	B1	1	
(e)		M1		Their critical activities and 3 others shown
		A1		Critical activities and 3 others correct
		A1	3	All correct, condone floats seen
(f)	34 (hrs)	B1	1	
(g)	62 (hrs)	B1	1	
	Total		**13**	

MD02

Q	Solution	Marks	Total	Comments
2(a)	$\begin{matrix} & & & & \text{Min} \\ & \begin{pmatrix} 4 & -1 & 2 & 3 \\ 4 & 6 & 3 & 7 \\ 1 & 3 & -2 & 4 \end{pmatrix} & & & \begin{matrix} -1 \\ 3 \\ -2 \end{matrix} \\ \text{Max} & 4 & 6 & 3 & 7 \end{matrix}$			
	Maximin (row) = 3	M1		Either correct, including correct values
	Minimax (col) = 3	A1 CSO		Both correct, written as equations PI by next line
	As Maximin (row) = Minimax (col) There is a stable solution	E1		Must have equation and statement and scored first 2 marks
	$\left.\begin{matrix}(\text{Play safe})\ (\text{H}) & B \\ (\text{Play safe})\ (\text{W}) & F\end{matrix}\right\}$	B1	4	Both correct
(b)	Saddle point (B, F)	B1	1	
	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 A1		3 rows correct from row reduction All correct
	$\begin{pmatrix} \cancel{8} & \cancel{5} & \cancel{0} & 9 & 6 \\ \cancel{0} & \cancel{1} & \cancel{0} & 4 & 2 \\ 1 & \cancel{0} & 2 & 2 & 1 \\ 4 & \cancel{0} & 3 & 7 & 4 \\ \cancel{0} & \cancel{0} & \cancel{0} & \cancel{0} & \cancel{0} \end{pmatrix}$ (Zeros correctly covered by 4 lines)	B1F		**Alternatives** 
	Covered in 4 lines, not optimal (reduce by 1)	E1		*
	$\begin{matrix} \cancel{8} & \cancel{5} & \cancel{0} & 8 & 5 \\ \cancel{0} & \cancel{1} & \cancel{0} & 3 & 1 \\ 1 & \cancel{0} & 2 & 1 & 0 \\ \cancel{4} & \cancel{0} & 3 & 6 & 3 \\ 1 & 1 & 1 & 0 & 0 \end{matrix}$	B1		7 (8) 5 (6) 0 (0) 8 (9) 5 (6) 0 (0) 2 (2) 1 (0) 4 (4) 2 (2) 0 (0) 0 (0) 2 (1) 1 (1) 0 (0) 3 (3) 0 (0) 3 (2) 6 (6) 3 (3) 0 (0) 1 (1) 1 (0) 0 (0) 0 (0)
	5 lines needed, optimal	(E1)		*or earned here
	Match *WC*, *XA*, *YE*, *ZB*, (*–D*)	B1		
	Value = 151	B1	8	
	Total		**9**	

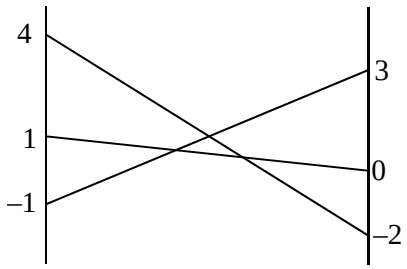
MD02

Q	Solution	Marks	Total	Comments
(4)(a)(i)	Max Flow = 50 (Min cut = 50)	E1		Either statement
(ii)	$35 \leq$ max flow ≤ 50 (or min cut)	E1, E1		E1 for strict inequalities
(iii)	Error or contradiction	E1	4	oe
(b)	At F,			
	flow in ≥ 8 flow out ≤ 7	M1 A1	2	Stating F and one of the 'flows'
	Total		**6**	

MD02

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

MD02

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 K plays A prob p C prob $1-p$			
	P plays D, K wins $-2p+4(1-p)$ $(=4-6p)$ E, K wins $1-p$ F, K wins $3p-1(1-p)$ $(=-1+4p)$	M1 A1		Allow 2 expressions in unsimplified form All 3 correct
		M1 A1		Must have 3 lines With values shown
	Max at $1-p=-1+4p$	M1		Identifying correct maximum from their graph
	$p=\frac{2}{5}$			
	$(K$ plays$)$ A prob $\frac{2}{5}$, C prob $\frac{3}{5}$	A1		Both stated, coming from equating correct two equations and M2 scored
	Value of game $=\frac{3}{5}$	B1	7	

MD02

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

MD02

<table>
<tr><th>Q</th><th>Solution</th><th>Marks</th><th>Total</th><th>Comments</th></tr>
<tr><td>7(a)</td><td>
<table>
<tr><th>Stage</th><th>State</th><th>From</th><th>Value</th></tr>
<tr><td>1</td><td>G</td><td>I</td><td>15</td></tr>
<tr><td></td><td>H</td><td>I</td><td>12</td></tr>
<tr><td>– –</td><td>– –</td><td>– –</td><td>– –</td></tr>
<tr><td>2</td><td>E</td><td>G</td><td>15+15 = 30 ←</td></tr>
<tr><td></td><td></td><td>H</td><td>12+16 = 28</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>F</td><td>G</td><td>15+13=28</td></tr>
<tr><td></td><td></td><td>H</td><td>12+17= 29 ←</td></tr>
<tr><td>– –</td><td>– –</td><td>– –</td><td>– – – – – –</td></tr>
<tr><td>3</td><td>B</td><td>E</td><td>30+16 = 46</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>C</td><td>E</td><td>30+14 = 44 ←</td></tr>
<tr><td></td><td></td><td>F</td><td>29+12 = 41</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>D</td><td>F</td><td>29+15 = 44</td></tr>
<tr><td>– –</td><td>– –</td><td>– –</td><td>– – – – – –</td></tr>
<tr><td>4</td><td>A</td><td>B</td><td>46+12 = 58</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>C</td><td>44+20= 64 ←</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>D</td><td>44+18 = 62</td></tr>
</table>
</td><td>B1

M1
m1

A1

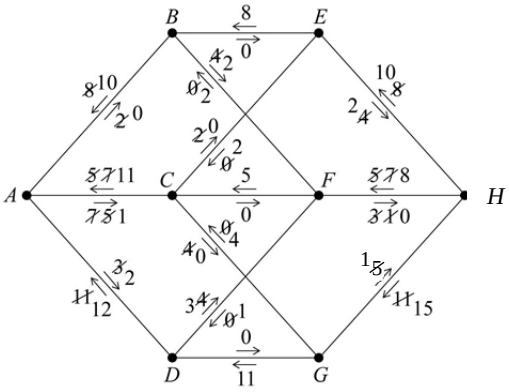
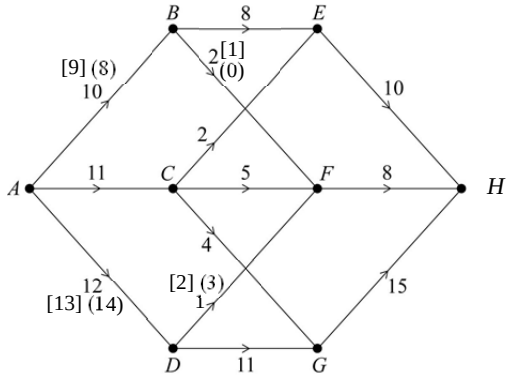
m1
A1
B1</td><td>7</td><td>Stage 2 values correct

Calculating 4 values at stage 3
Using max values at E and F

All 4 values correct

Using max at C
All correct
Identifying 64 as maximum value</td></tr>
<tr><td>(b)</td><td>Route A C E G I</td><td>B1</td><td>1</td><td></td></tr>
<tr><td></td><td>Total</td><td></td><td>8</td><td></td></tr>
</table>

MD02

Q	Solution	Marks	Total	Comments
(8)(a)	*A B E H* 8 *A C F H* 5 *A D G H* 11	B1	1	
(b)(i)	*ACEH* 2	M1		One correct route and flow
	ACGH 4	A1		At least one other correct
	Either *ADFH* 1 and *ABFH* 2	A1		All correct
	Or *ADFH* 3			
		M1		Forward and back flows on diagram
		A1	5	All correct
(ii)	Max flow 33	B1		
		B1	2	OE
(c)	Cut through *BE, CE, FH, CG, DG*	B1	1	
	Total		**9**	
	TOTAL		**75**	

Version 1.0

General Certificate of Education (A-level)
June 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.

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

Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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

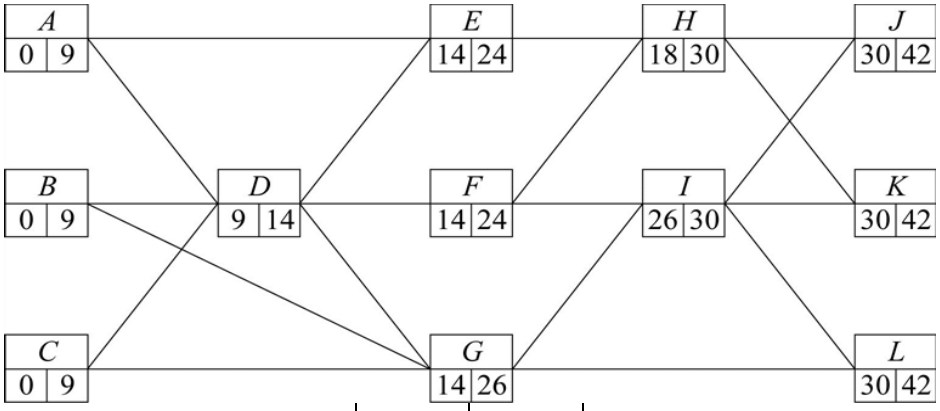
Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

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**.

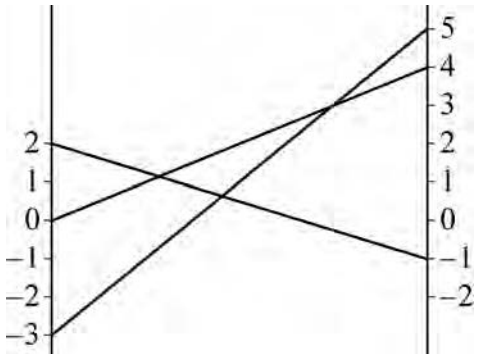
Otherwise we require evidence of a correct method for any marks to be awarded.

Q	Solution	Marks	Total	Comments
1(a)				
		M1		Forward pass, correct at *D, E, F, G*
		A1		All correct
		M1		Backward pass, correct at *H, I, G* ft
		A1	4	All correct
(b)	*C D G I J* only	B1	1	
(c)	6	B1ft	1	Their (latest – earliest – 4)
(d)	*H* delayed by 4	E1		
	K delayed by 5	B1		
	New time 51	B1	3	51 scores 3/3
	Total		**9**	
2(a)	19	B1	1	
(b)	*E*	B1	1	
(c)	*C*	B1	1	
(d)	$x = 8$			
	$y = 13$			
	$z = 39$	B1 × 3	3	
(e)	76	B1	1	
(f)	83	B1	1	
	Total		**8**	

Q	Solution	Marks	Total	Comments
3(a)	Reduce columns $\begin{pmatrix} 0 & 12 & 13 & 2 & 0 \\ 25 & 32 & 11 & 20 & 20 \\ 5 & 12 & 2 & 8 & 25 \\ 15 & 17 & 21 & 35 & 15 \\ 0 & 0 & 0 & 0 & 7 \end{pmatrix}$	M1 A1		
	Reduce rows $\begin{pmatrix} 0 & 12 & 13 & 2 & 0 \\ 14 & 21 & 0 & 9 & 9 \\ 3 & 10 & 0 & 6 & 23 \\ 0 & 2 & 6 & 20 & 0 \\ 0 & 0 & 0 & 0 & 7 \end{pmatrix}$			AG
	$k = 9$	B1	3	
(b)	4 lines drawn on given table	B1		
	Subtract/add 2 $\begin{pmatrix} 0 & 10 & 13 & 0 & 0 \\ 14 & 19 & 0 & 7 & 9 \\ 3 & 8 & 0 & 4 & 23 \\ 0 & 0 & 6 & 18 & 0 \\ 2 & 0 & 2 & 0 & 9 \end{pmatrix}$	M1 A1		Condone one slip Correct table with 4 lines shown
	Subtract/add 3 $\begin{pmatrix} 0 & 10 & 16 & 0 & 0 \\ 11 & 16 & 0 & 4 & 6 \\ 0 & 5 & 0 & 1 & 20 \\ 0 & 0 & 9 & 18 & 0 \\ 2 & 0 & 5 & 0 & 9 \end{pmatrix}$	m1 A1	5	Condone one slip All correct with no errors seen, including 5 lines drawn
(c)	Match *XA*, *WC* + *VD*, *YE*, *ZB* or *VE*, *YB*, *ZD*	M1 A1 A1	3	And no extras
(d)	525	B1	1	
	Total		**12**	

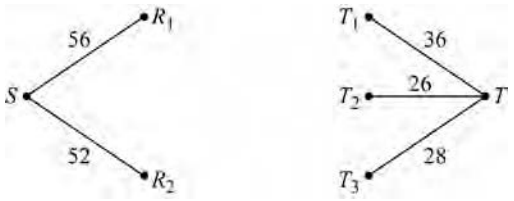
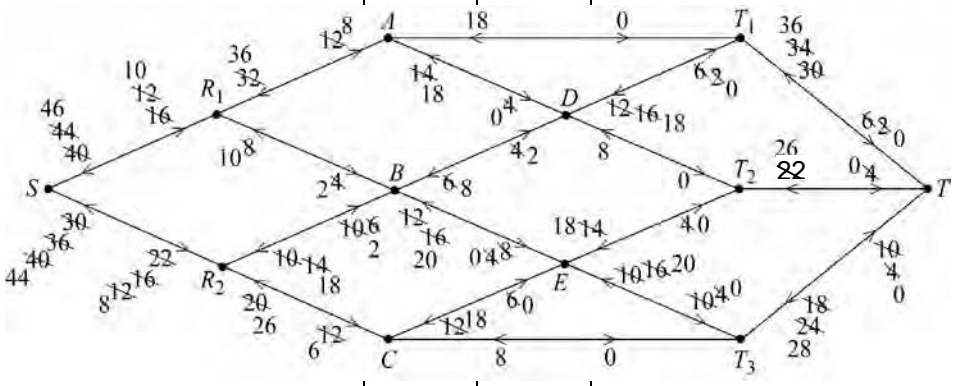
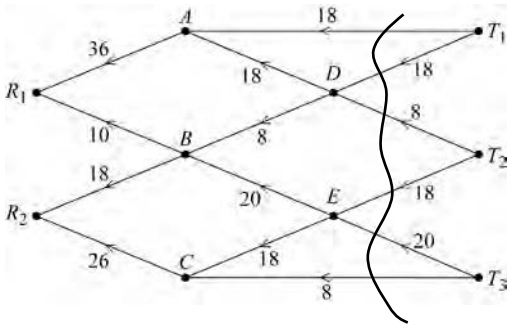
Q	Solution	Marks	Total	Comments
4				
		B1		All correct
		M1		7 values at stage 2
		m1		Choosing max at *E*, *F*, *G* (PI), but must be using maximin
		A1		All correct at stage 2
		m1		7 values at stage 3, must have scored M2 earlier
		A1		All correct at stage 3
		A1		All correct (whole table)
		B1		For 14 as final value indicated or stated
	Route *A C G I K*	B1	9	Or reverse
	Total		**9**	

Stage	State	From	Value
1	*H*	*K*	18
	I	*K*	15
	J	*K*	12
2	*E*	*H*	(17)
		I	15
	F	*H*	(15)
		I	14
		J	12
	G	*I*	(14)
		J	12
3	*B*	*E*	11
		F	(13)
	C	*E*	12
		F	13
		G	(14)
	D	*F*	(15)
		G	14
4	*A*	*B*	12
		C	(14)
		D	13

Q	Solution	Marks	Total	Comments
5(a)	R min $-4,\ -5,\ -2$ plays C	B1		Either *C* or *E* stated
	J max $4,\ 1,\ 3$ plays E	B1		Both *C* and *E* stated
		E1	3	and all values shown
(b)	maximin R = $-2 \neq 1$ = minimax J	E1	1	Correct values must be stated
(c)	(For Juliet,) col E dominates col D	E1	1	
(d)(i)	Signs changed as J gains = R losses	E1		
	Gains written as rows	E1	2	
(ii)	Let J play E prob p			
	F $(1-p)$			
	If R plays A, J wins $4p$			
	B $5p-3(1-p)$	M1		2 correct expressions seen
	C $-p+2(1-p)$	A1		All correct
	$[\text{gives } 4p,\ 8p-3,\ 2-3p]$			
		m1		Must have 3 lines
		A1		All correct with values shown
	Max at $8p-3=2-3p$	m1		Identifies correct max from their graph
	$p=\frac{5}{11}$	A1		
	(J plays)E prob $\frac{5}{11}$, F prob $\frac{6}{11}$	A1 CSO	7	
(iii)	Value of game $=\frac{7}{11}$	B1	1	
	Total		**15**	

Q	Solution	Marks	Total	Comments
6(a)	$\begin{array}{cccccccc} P & x & y & z & r & s & t & \text{Value} \\ \hline 1 & -4 & -3 & -1 & 0 & 0 & 0 & 0 \\ 0 & \textcircled{2} & 1 & 1 & 1 & 0 & 0 & 25 \\ 0 & 1 & 2 & 1 & 0 & 1 & 0 & 40 \\ 0 & 1 & 1 & 2 & 0 & 0 & 1 & 30 \end{array}$	B2,1,0	2	All correct, 3 rows correct
(b)	$\begin{array}{cccccccc} 1 & 0 & -1 & 1 & 2 & 0 & 0 & 50 \\ 0 & 1 & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & 0 & 0 & \frac{25}{2} \\ 0 & 0 & \textcircled{\frac{3}{2}} & \frac{1}{2} & -\frac{1}{2} & 1 & 0 & \frac{55}{2} \\ 0 & 0 & \frac{1}{2} & \frac{3}{2} & -\frac{1}{2} & 0 & 1 & \frac{35}{2} \end{array}$	B1 M1 A1	3	Pivot, x-col: 12.5, 40, 30 seen and correct pivot chosen Row operations All correct
(c)(i)	$\begin{array}{cccccccc} 1 & 0 & 0 & \frac{4}{3} & \frac{5}{3} & \frac{2}{3} & 0 & \frac{205}{3} \\ 0 & 1 & 0 & \frac{1}{3} & \frac{2}{3} & -\frac{1}{3} & 0 & \frac{10}{3} \\ 0 & 0 & 1 & \frac{1}{3} & -\frac{1}{3} & \frac{2}{3} & 0 & \frac{55}{3} \\ 0 & 0 & 0 & \frac{4}{3} & -\frac{1}{3} & -\frac{1}{3} & 1 & \frac{25}{3} \end{array}$	B1 M1 A1	3	Pivot, y-col: their 25, 55/3, 35 seen and correct pivot chosen Row operations All correct
(ii)	$\text{Max}P = \frac{205}{3}$	B1		Condone optimal, etc
	$x = \frac{10}{3},\ y = \frac{55}{3},\ z = 0$	B1		Ft on x and y
	$r = 0,\ s = 0,\ t = \frac{25}{3}$	B1ft	3	All 3 must be stated

Q	Solution	Marks	Total	Comments
6	**Alternative**			**Comments as above**
(a)	$\begin{array}{cccccccc} P & x & y & z & r & s & t & \text{Value} \\ 1 & -4 & -3 & -1 & 0 & 0 & 0 & 0 \\ 0 & \textcircled{2} & 1 & 1 & 1 & 0 & 0 & 25 \\ 0 & 1 & 2 & 1 & 0 & 1 & 0 & 40 \\ 0 & 1 & 1 & 2 & 0 & 0 & 1 & 30 \end{array}$		(2)	
(b)	$\begin{array}{cccccccc} 1 & 0 & -1 & 1 & 2 & 0 & 0 & 50 \\ 0 & 2 & 1 & 1 & 1 & 0 & 0 & 25 \\ 0 & 0 & \textcircled{3} & 1 & -1 & 2 & 0 & 55 \\ 0 & 0 & 1 & 3 & -1 & 0 & 2 & 35 \end{array}$		(3)	
(c)(i)	$\begin{array}{cccccccc} 3 & 0 & 0 & 4 & 5 & 2 & 0 & 205 \\ 0 & 6 & 0 & 2 & 4 & -2 & 0 & 20 \\ 0 & 0 & 3 & 1 & -1 & 2 & 0 & 55 \\ 0 & 0 & 0 & 8 & -2 & -2 & 6 & 50 \end{array}$		(3)	
(ii)	$P = \frac{205}{3}$ $x = \frac{10}{3},\ y = \frac{55}{3},\ z = 0$ $r = s = 0,\ t = \frac{25}{3}$		(3)	
	Total		**11**	

Q	Solution	Marks	Total	Comments
7(a)		B1 B1	 2	Edges with values ≥ 56, 52 Edges with values ≥ 36, 26, 28
b(i)		M1 A1	 	initial diagram with forward/back flows Fully correct diagram
	$S\,R_1\,A\,D\,T_1\,T$ 4 $S\,R_1\,B\,D\,T_1\,T$ 2 $S\,R_2\,C\,E\,T_3\,T$ 6 $S\,R_2\,B\,E\,T_2\,T$ 4 $S\,R_2\,B\,E\,T_3\,T$ 4	M1 A1 A1	 5	One correct path and flow At least one other correct path and flow all correct (ignore connections to S and T)
(ii)	Max flow 90 	B1 B1	 2	
(c)	Cut through (shown)	B1		PI by correct list
	AT_1, DT_1, DT_2, ET_2, ET_3, CT_3	B1	2	OE
	Total		**11**	
	TOTAL		**75**	

A-LEVEL
MATHEMATICS

Decision 2 – MD02
Mark scheme

6360
June 2014

Version/Stage Final V1.0

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

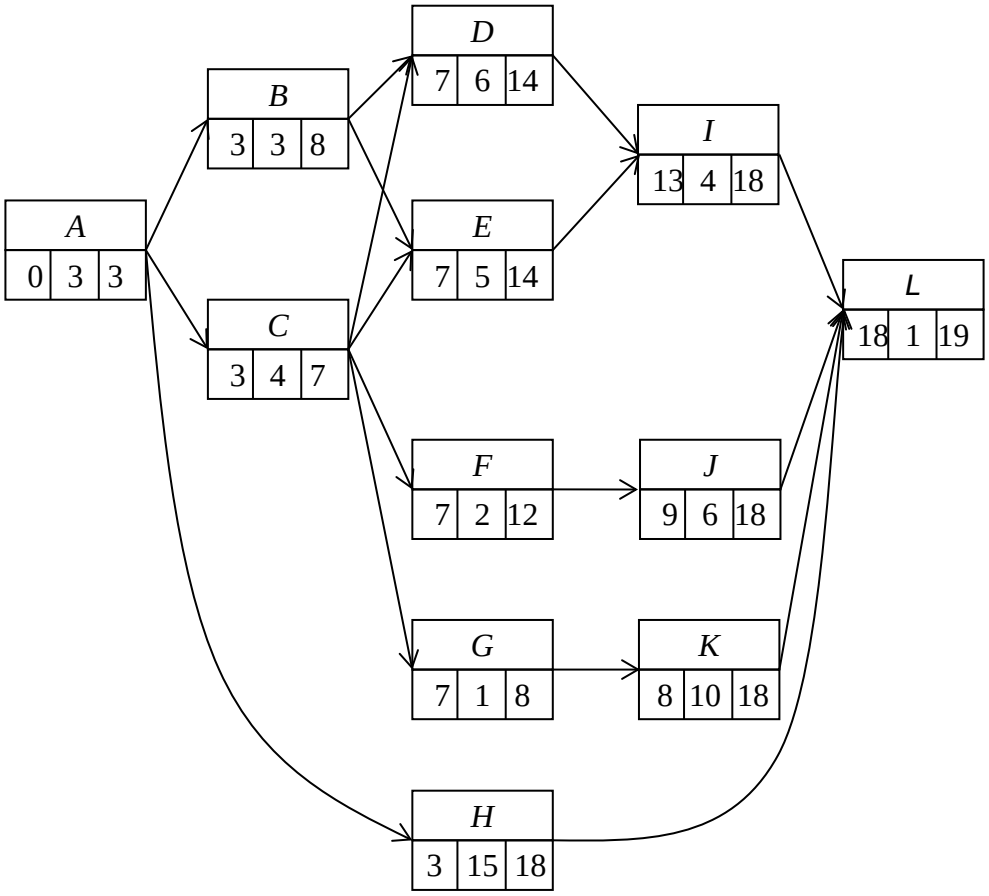
Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

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**.

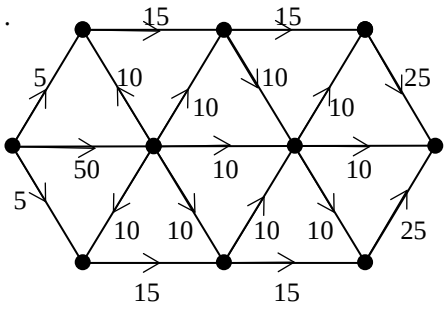
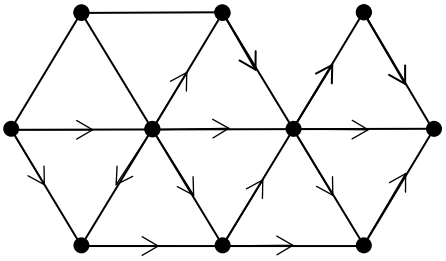
Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

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.

Q	Solution	Mark	Total	Comment
1(a)				
(a)		M1 A2	3	Network diagram -1 each independent error (ignore extra 'end' box)
(b)		M1 A1	2	Forward pass, correct at *D*, *E*, *F*
(c)		M1 A1	2	Backward pass, correct at 3 of *D*, *E*, *F*, *G* ft
(d)	*A*,*C*,*G*,*K*,*L* *(A)*,*H*,*(L)*	B1 B1	2	−1 for each extra
	Total		**9**	

Q	Solution	Mark	Total	Comment
2(a)	Row min –4, 0, –5	**M1**		Attempt to find maximin and minimax
	Max (row min) = 0			
	Col max 5, 3, 0, 1			Accept '*F* dominates *G*', col max 5, 3, 0
	Min (col max) = 0	**A1**		All rowmin and colmax values correct and maximin and minimax identified
	Max (row min) = Min (col max) = 0	**E1**		Full statement involving maximin and minimax and both values = 0
	Hence game has a stable solution.			If using dominance: Reduction to 2x2 M1 Reduction to 1x1 A1 Final statement E1
	Alex plays *B* Roberto plays *F*	**B1**	**4**	
(b)	Saddle point (*B*, *F*) ONLY	**B1**	**1**	
	Total		**5**	

Q	Solution	Mark	Total	Comment
3(a)	$C_1 = 60$	**B1**		
	$C_2 = 80$	**B1**	**2**	
(b)	e.g. . 	**M1** **A1**	**2**	Correct at *D*
(c)(i)		**M1**		Correct to *D*, *E*, *F* either by inspection or flow augmentation
		A1		All correct
	oe			
	MAX = 45	**B1**	**3**	
(ii)	CUT THRU' *EG*,*DG*, *DF*, *DC*, *AC*	**B1**		Or {*A*,*B*,*D*,*E*} {*C*,*FG*,,*H*,*IJ*}
	Max flow = Min cut	**E1**	**2**	Must have scored B1,B1 in point (C)
	Total		**9**	

Q	Solution	Mark	Total	Comment
4(a)				
		B1		1st and 2nd row correct
		B1	**2**	1st and 3rd row correct
(b)				
		B1		Correct pivot 'y, 3' chosen and 11/3, 21/4 seen
		M1		Row operations
		A1	**3**	All correct
(c)				
		B1		Correct pivot 'x, 5' chosen and 19/5, 11 seen
		M1		Row operations
		A1	**3**	All correct
(d)	$P = 25.8$ $z = r = t = 0$ $x = 3.8$, $y = 2.4$	**B1** **B1** **B1**	**3**	
	Total		**11**	

P	***x***	***y***	***z***	***r***	***t***	
1	–3	–6	–2	0	0	0
0	1	3	2	1	0	11
0	3	4	2	0	1	21

P	***x***	***y***	***z***	***r***	***t***	
1	–1	0	2	2	0	22
0	1	3*	2	1	0	11
0	5	0	–2	–4	3	19

Or

P	***x***	***y***	***z***	***r***	***t***	
1	–1	0	2	2	0	22
0	$\frac{1}{3}$	1	$\frac{2}{3}$	$\frac{1}{3}$	0	$\frac{11}{3}$
0	$\frac{5}{3}$	0	$-\frac{2}{3}$	$-\frac{4}{3}$	1	$\frac{19}{3}$

P	***x***	***y***	***z***	***r***	***t***	
5	0	0	8	6	3	129
0	0	15	12	9	–3	36
0	5*	0	-2	–4	3	19

Oe

P	***x***	***y***	***z***	***r***	***t***	
1	0	0	$\frac{8}{5}$	$\frac{6}{5}$	$\frac{3}{5}$	$\frac{129}{5}$
0	0	1	$\frac{4}{5}$	$\frac{3}{5}$	$-\frac{1}{5}$	$\frac{12}{5}$
0	1	0	$-\frac{2}{5}$	$-\frac{4}{5}$	$\frac{3}{5}$	$\frac{19}{5}$

Q	Solution	Mark	Total	Comment
5(a)	*A* dominates *B*	**E1**	**1**	
(b)	Reduced matrix			
	<table><tr><td></td><td>p</td><td>q</td><td>$1–p–q$</td></tr><tr><td>A</td><td>4</td><td>1</td><td>–1</td></tr><tr><td>C</td><td>–2</td><td>0</td><td>3</td></tr></table>	**E1**		Use of '$1–p–q$'
	Mark plays *A*, Owen loses			
	$4p + q + –1(1–p–q)$	**M1**		One correct expression or reverse
	Mark plays *C*, Owen loses			
	$–2p + 3(1–p–q)$	**A1**		Both correct or reverse
	$5p + 2q = 1.6$	**m1**		Correct use of 0.6 (or $–0.6$) Condone simplified equations
	$–5p – 3q = –2.4$	**A1**		2 correct equations
	$q = 0.8$	**A1**		At least 2 correct
	$p = 0$			
	$1–p–q = 0.2$			
	Owen plays *D* with prob 0 Owen plays *E* with prob 0.8 Owen plays *F* with prob 0.2	**B1**	**7**	All correct in context of *D*, *E*, *F*
	Total		**8**	

Q	Solution	Mark	Total	Comment
6(a)	Stage 2	**B1**		4 correct values
		M1		Choosing 2 'mins' out of 4 expressions
	Stage 3	**m1**		4 expressions
		A1		*EG* chosen
	Stage 4	**m1**		4 expressions, 1 in terms of x
	Stage 5	**B1**		Final value 48, indicated or stated
		A1	**7**	All correct (complete table)
(b)	$x + 41 = 48$	**M1**		Their $(x + 8 + k)$ = their (min)
	$x = 7$	**A1**	**2**	
(c)	*A B D G I K* *A B E G I K* *A C F H I K*	**B1** **B1** **B1**	**3**	Condone reverse (x3)
	Total		**12**	

Stage	State	From	Calculation	Value
1	*I*	*K*	12	12
	J	*K*	14	14
2	*G*	*I*	15 + 12	27
		J	14 + 14	(28)
	H	*I*	12 + 13	25
		J	14 + 12	(26)
3	*D*	*G*	$27 + x + 2$	$29 + x$
	E	*G*	27 + 9	36
		H	25 + 12	(37)
	F	*H*	25 + 13	38
4	*B*	*D*	$29 + x + 4$	$33 + x$
		E	36 + 4	40
	C	*E*	36 + 9	(45)
		F	38 + 6	44
5	*A*	*B*	$33 + x + 8$	$41 + x$
		B	40 + 8	48
	A	*C*	44 + 4	48

Q	Solution	Mark	Total	Comment
7(a)	Row minima: $(x + 4), (x + 2), (x + 5)$	**M1** **A1**	**2**	1 correct All 3 correct
(b)	<table><tr><td>4</td><td>0</td><td>2</td><td>5</td></tr><tr><td>3</td><td>1</td><td>2</td><td>0</td></tr><tr><td>3</td><td>2</td><td>0</td><td>$x – 3$</td></tr><tr><td>2</td><td>$x – 4$</td><td>$11 – x$</td><td>0</td></tr></table>	**M1** **A1** **A1**		Using correct/'their' row minima 3 rows correct All correct
	Reduce cols to give			
	<table><tr><td>2</td><td>0</td><td>2</td><td>5</td></tr><tr><td>1</td><td>1</td><td>2</td><td>0</td></tr><tr><td>1</td><td>2</td><td>0</td><td>$x – 3$</td></tr><tr><td>0</td><td>$x – 4$</td><td>$11 – x$</td><td>0</td></tr></table>	**M1** **A1**		3 rows correct All correct
	4 lines needed to cover 0's	**E1**		oe
	Match *AZ*, *BW*, *CY*, *DX* stated	**B1**	**7**	
(c)	$4x+14= 42$	**M1**		Their expression = 42
	$x = 7$	**A1**	**2**	
	Total		**11**	

Q	Solution	Mark	Total	Comment
8(a)	$x = 4$ $y = 17$ $z = 17$	 **B1** **B1**	 **2**	 Any 2 correct All 3 correct
(b)	*B D G I K*	**B1**	**1**	
c(i)	Reduce *G* to 5 (as critical) oe	**E1**		Decrease *G* by 3
	Reduce *F* to 4 or 5 Reduce *F* to5	**E1** **E1**		Decrease *F* by 2 or 3 Decrease *F* by 2 Condone new values shown on diagram
	Don't reduce *E* (as path through E still not critical)	**E1**		
(ii)	25 (weeks)	**B1**		
(iii)	Cost (3 x 6 + 2 x 7) PI by 32 = £32 000	**M1** **A1**	 **7**	
	Total		**10**	
	TOTAL		**75**	

A-LEVEL
Mathematics

Decision 2 – MD02
Mark scheme

6360
June 2015

Version/Stage: Version 1.0: Final

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.

Q1	Solution	Mark	Total	Comment
1a	<table><tr><th>Activity</th><th>Predecessor(s)</th></tr><tr><td>A</td><td>-</td></tr><tr><td>B</td><td>-</td></tr><tr><td>C</td><td>-</td></tr><tr><td>D</td><td>A, B</td></tr><tr><td>E</td><td>B</td></tr><tr><td>F</td><td>B, C</td></tr><tr><td>G</td><td>D</td></tr><tr><td>H</td><td>D, E, F</td></tr><tr><td>I</td><td>G, H</td></tr><tr><td>J</td><td>G, H</td></tr></table>	**B1**	**1**	All correct
1b	<table><tr><th>Activity</th><th>Early</th><th>Late</th></tr><tr><td>A</td><td>0</td><td>7</td></tr><tr><td>B</td><td>0</td><td>5</td></tr><tr><td>C</td><td>0</td><td>5</td></tr><tr><td>D</td><td>7</td><td>13</td></tr><tr><td>E</td><td>5</td><td>13</td></tr><tr><td>F</td><td>5</td><td>13</td></tr><tr><td>G</td><td>13</td><td>19</td></tr><tr><td>H</td><td>13</td><td>19</td></tr><tr><td>I</td><td>19</td><td>28</td></tr><tr><td>J</td><td>19</td><td>28</td></tr></table>	**M1** **A1** **M1** **A1ft**	**4**	Forward pass, correct at G and H. All correct Back pass correct at D, E, F from their final total time All correct
1c	ADHJ BFHJ	**B1** **B1**	**2**	One correct Both correct, and no more
1d	1	**B1**	**1**	
1e	SCA Use of floats All correct	**M1** **B1** **A1**	**3**	Must be Gantt diagram Two of C, E, G, I correct
1f	65 (hours)	**B1**	**1**	
1g	34 (hours) Worker 1: A, C, F, G, J Worker 2: B, E, D, H, I	**M1** **A1**	**2**	Or any other correct allocation
	Total		**14**	

Q2	Solution	Mark	Total	Comment
2a	**Stan:** Row(min) (-3, -4, -3) Max(min) -3	**B1***		Earned here, all 3 values seen and -3 highlighted or stated, or BOTH correct playsafe stated.
	Playsafe 'A or C'	**B1**		Both needed
	Christine: Col(max) (3, 0, 2, 3) Min(max) 0	**(B1)***		Or here, all 4 values seen and 0 highlighted or stated, or correct playsafe stated
	Playsafe E	**B1**	**3**	
2b	Maximin = -3 ≠ 0 = Minimax	**E1**	**1**	
2c	Col E 'dominates' Col D Col F 'dominates' Col G Original matrix shows Christine's losses, but as zero-sum game multiply by -1 to show Christine's gains Matrix transposed as now seen from Christine's perspective	**E1** **E1** **E1** **E1**	**4**	
	Total		**8**	

<table>
<tr><th>Q3</th><th>Solution</th><th>Mark</th><th>Total</th><th>Comment</th></tr>
<tr><td>3</td><td>Add extra column
Reduce cols:

<table><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0.44</td><td>0.15</td><td>0.26</td><td>0.35</td><td>0</td></tr><tr><td>0.47</td><td>0.2</td><td>0.24</td><td>0.48</td><td>0</td></tr><tr><td>0.2</td><td>0.16</td><td>0.21</td><td>0.31</td><td>0</td></tr><tr><td>0.07</td><td>0.04</td><td>0.11</td><td>0.04</td><td>0</td></tr></table>
Reduce by 0.04 (Covered with 2 lines),

<table><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0.04</td></tr><tr><td>0.4</td><td>0.11</td><td>0.22</td><td>0.31</td><td>0</td></tr><tr><td>0.43</td><td>0.16</td><td>0.2</td><td>0.44</td><td>0</td></tr><tr><td>0.16</td><td>0.12</td><td>0.17</td><td>0.27</td><td>0</td></tr><tr><td>0.03</td><td>0</td><td>0.07</td><td>0</td><td>0</td></tr></table>
Reduce by 0.11, (Covered with 3 lines)

<table><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0.15</td></tr><tr><td>0.29</td><td>0</td><td>0.11</td><td>0.2</td><td>0</td></tr><tr><td>0.32</td><td>0.05</td><td>0.09</td><td>0.33</td><td>0</td></tr><tr><td>0.05</td><td>0.01</td><td>0.06</td><td>0.16</td><td>0</td></tr><tr><td>0.03</td><td>0</td><td>0.07</td><td>0</td><td>0.11</td></tr></table>
Reduce by 0.05 (in 1 or more iterations) (Covered with 4 lines)

<table><tr><td>0</td><td>0.05</td><td>0</td><td>0</td><td>0.2</td></tr><tr><td>0.24</td><td>0</td><td>0.06</td><td>0.15</td><td>0</td></tr><tr><td>0.27</td><td>0.05</td><td>0.04</td><td>0.28</td><td>0</td></tr><tr><td>0</td><td>0.01</td><td>0.01</td><td>0.11</td><td>0</td></tr><tr><td>0.03</td><td>0.05</td><td>0.07</td><td>0</td><td>0.16</td></tr></table>
Correct final matrix, with no errors seen

Covered by 5 lines, (so optimal)
(Match) A3, B2, D1, E4
(Time) 36.82 (secs)</td><td>B1

M1

A1

m1

A1

m1

m1

A1

E1
B1
B1</td><td></td><td>with all values the same, at least 10.31

At least 3 cols correct.

All correct

PI, by values in following matrix

All correct

PI, by values in following matrix

Or,
Reduce by 0.01 (Covered with 4 lines)

<table><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0.16</td></tr><tr><td>0.29</td><td>0</td><td>0.11</td><td>0.2</td><td>0.01</td></tr><tr><td>0.31</td><td>0.04</td><td>0.08</td><td>0.32</td><td>0</td></tr><tr><td>0.04</td><td>0</td><td>0.05</td><td>0.15</td><td>0</td></tr><tr><td>0.03</td><td>0</td><td>0.07</td><td>0</td><td>0.12</td></tr></table>
AND
Covered with 4 lines, reduce by 0.04

<table><tr><td>0</td><td>0.04</td><td>0</td><td>0</td><td>0.20</td></tr><tr><td>0.25</td><td>0</td><td>0.07</td><td>0.16</td><td>0.01</td></tr><tr><td>0.27</td><td>0.04</td><td>0.04</td><td>0.28</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0.01</td><td>0.11</td><td>0</td></tr><tr><td>0.03</td><td>0.04</td><td>0.07</td><td>0</td><td>0.16</td></tr></table>
There are other correct combinations but must reduce by 0.05

Must see statement
Condone C5</td></tr>
<tr><td></td><td>Total</td><td></td><td>11</td><td></td></tr>
</table>

Q 4	Solution	Mark	Total	Comment
4a	P x y z r t u V 1 -2 -3 -4 0 0 0 0 0 1 1 2 1 0 0 20 0 3 2 1 0 1 0 30 0 2 3 1 0 0 1 40	**M1** **A1**	 2	3 rows correct All correct
bi	Row 2 in *z*-col 20/2 (= 10) (min), 30/1 (= 30), 40/1 (= 40) **For all following matrices, accept any multiple of any row shown**	**B1** **E1**	 2	 May be seen in part (a)
b ii	1 0 -1 0 2 0 0 40 0 0.5 0.5 1 0.5 0 0 10 0 2.5 1.5 0 -0.5 1 0 20 0 1.5 2.5 0 -0.5 0 1 30 **OR** 1 0 -1 0 2 0 0 40 0 1 1 2 1 0 0 20 0 5 3 0 -1 2 0 40 0 3 5 0 -1 0 2 60	**M1** **A1** **A1**	 3	SCA – row reduction, 1 row correct (other than pivot row - shaded) 3 rows correct All 4 correct As above

ci Pivot from *y*-col
10/0.5 (= 20), 20/1.5 (= 13.3), 30/2.5 (= 12)

1	0.6	0	0	1.8	0	0.4	52
0	0.2	0	1	0.6	0	-0.2	4
0	1.6	0	0	-0.2	1	-0.6	2
0	0.6	1	0	-0.2	0	0.4	12

B1ft — May be seen in part (b)(ii)

m1 — SCA – row reduction, 1 row correct (other than pivot row - shaded), must have scored at least **M1** in (b)(ii), but allow any one row correct from a previous error

A1 3 — All 4 correct

OR

Pivot from *y*-col
20/1 (= 20), 40/3 (= 13.3), 60/5 (= 12)

5	3	0	0	9	0	2	260
0	2	0	10	6	0	-2	40
0	16	0	0	-2	10	-6	20
0	3	5	0	-1	0	2	60

As above

For this part, answers must be from a row of 'positives' in 'profit'

ii Max/Optimal $P = 52$ — **B1ft** — Must include Max/Optimal
$x = 0,\ y = 12,\ z = 4$ — **B1ft**
$r = 0,\ t = 2,\ u = 0$ — **B1ft** 3 — Must be non-negative values

	Total	**13**	

Q5	Solution	Mark	Total	Comment
5a	<table><tr><th>Stage</th><th>State</th><th>From</th><th>Value</th></tr><tr><td>1</td><td>H</td><td>K</td><td>2.7</td></tr><tr><td></td><td>I</td><td>K</td><td>2.3</td></tr><tr><td></td><td>J</td><td>K</td><td>2.5</td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td>2</td><td>E</td><td>H</td><td>2.7</td></tr><tr><td></td><td></td><td>I</td><td>2.4*</td></tr><tr><td></td><td>F</td><td>H</td><td>2.7</td></tr><tr><td></td><td></td><td>I</td><td>2.6</td></tr><tr><td></td><td></td><td>J</td><td>2.5*</td></tr><tr><td></td><td>G</td><td>I</td><td>2.6*</td></tr><tr><td></td><td></td><td>J</td><td>2.9</td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td>3</td><td>B</td><td>E</td><td>2.8</td></tr><tr><td></td><td></td><td>F</td><td>2.7*</td></tr><tr><td></td><td>C</td><td>E</td><td>2.8</td></tr><tr><td></td><td></td><td>F</td><td>2.5*</td></tr><tr><td></td><td></td><td>G</td><td>2.6</td></tr><tr><td></td><td>D</td><td>F</td><td>2.8</td></tr><tr><td></td><td></td><td>G</td><td>2.7*</td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td>4</td><td>A</td><td>B</td><td>2.7</td></tr><tr><td></td><td></td><td>C</td><td>2.5*</td></tr><tr><td></td><td></td><td>D</td><td>2.7</td></tr></table> Route ACFJK	 **B1** **M1** **A1** **B1** **m1** **A1** **B1** **A1** **B1**	 **9**	 7 values at stage 2 Using minimax – choosing at least 2 of EI, FJ, GI (PI by values seen at stage 3) All values correct at stage 2 7 values at stage 3 At least 5 values correct All values correct at stage 3 3 values at stage 4 **All** correct, with 2.5 identified as min In this order and not reverse
b	(Tom's route) ACGIK (Max height) 260 metres oe	**B1** **B1**	**2**	In this order and not reverse Must have units
	Total		**11**	

Q6	Solution	Mark	Total	Comment
6a	100	**B1**	**1**	
bi	<table><tr><td>Path</td><td>Value</td></tr><tr><td>ABDGJ</td><td>3</td></tr><tr><td>ABDEGJ</td><td>1</td></tr><tr><td>AEHJ</td><td>3</td></tr><tr><td>AEGJ</td><td>1</td></tr><tr><td>AFIJ</td><td>5</td></tr><tr><td>AEIJ</td><td>5</td></tr></table>	**B1** **M1** **A1** **A1**		Correct initial diagram on AB, AE, AC Showing forward and back flows One correct path (including value) 3 correct paths (including values) Total increase in flows of exactly 18
	Oe these are examples of a set of complete flows, but they are not unique	**A1**		Fully correct diagram
			5	
ii	Max flow 118 Correct diagram	**M1** **A1**	**2**	
c	Cut through GJ, GH, EH, EI, FI Edges listed	**B1** **B1**	**2**	Could be shown on diagram
d	Current flow is 35, subtract 5 113	**E1** **B1**	**2**	113 scores 2/2
	Total			

Q	Solution	Mark	Total	Comment
7	Marks for this question can be earned in either order			Eg, finding x first from simult equs.
a	Arsene plays A with prob p, plays B with prob 1-p Jose plays C: A wins p(x+3) + (1-p)(x+1) Jose plays D: A wins p + 3(1-p) p + 3(1-p) = 2.5 (p = 0.25) Arsene plays A with prob 0.25 Arsene plays B with prob 0.75	 **B1** **B1** **M1** **A1**	 **4**	 **oe** could be seen in part (b) **oe** Need both statements
b	0.25(x+3) + 0.75(x+1) = 2.5 x = 1	**M1** **A1**	 **2**	Replacing p by 0.25 in a correct expression, and equating to 2.5
	Total		**6**	