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.

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Key to mark scheme abbreviations

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

No Method Shown

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

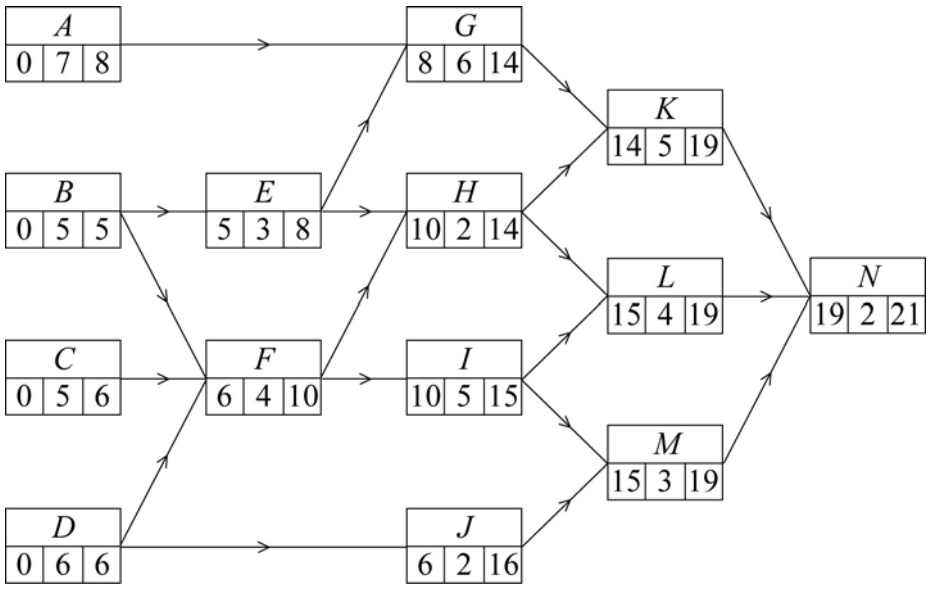
Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn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

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

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

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

MD02

Q	Solution	Marks	Total	Comments
1(a)				
	Forward pass	M1		condone one slip (follow through)
		A1		all correct
	Backward pass	M1		condone one slip (follow through)
		A1	4	all correct
(b)	Critical paths $B\ E\ G\ K\ N$	M1		first path correct
	$D\ F\ I\ L\ N$	A1		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		3 of these with correct start and duration
		A1		3 correct with correct slack indicated
		A1	5	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)
	$\begin{array}{\|c\|c\|c\|c\|c\|c\|c\|}\hline 1 & 2-k & 0 & 7 & 0 & 2 & 36 \\ \hline 0 & \frac{5}{3} & 0 & 2 & 1 & -\frac{1}{3} & 5 \\ \hline 0 & \frac{1}{3} & 1 & 2 & 0 & \frac{1}{3} & 6 \\ \hline \end{array}$	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
	$\begin{array}{\|c\|c\|c\|c\|c\|c\|c\|}\hline 1 & 0 & 0 & \frac{41}{5} & \frac{3}{5} & \frac{9}{5} & 39 \\ \hline 0 & 1 & 0 & \frac{6}{5} & \frac{3}{5} & -\frac{1}{5} & 3 \\ \hline 0 & 0 & 1 & \frac{8}{5} & -\frac{1}{5} & \frac{2}{5} & 5 \\ \hline \end{array}$	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**	

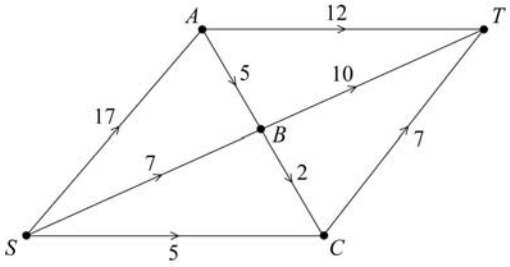
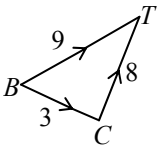
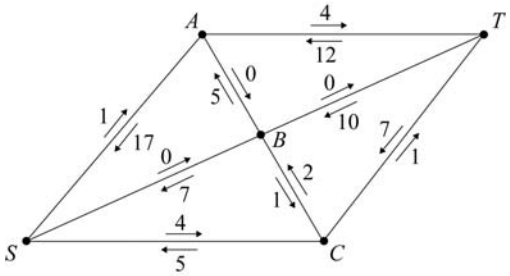
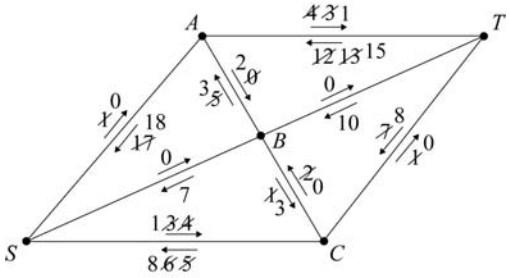
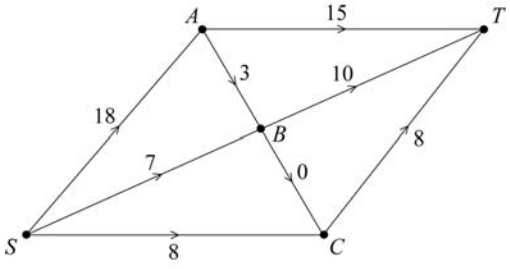
MD02

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**	

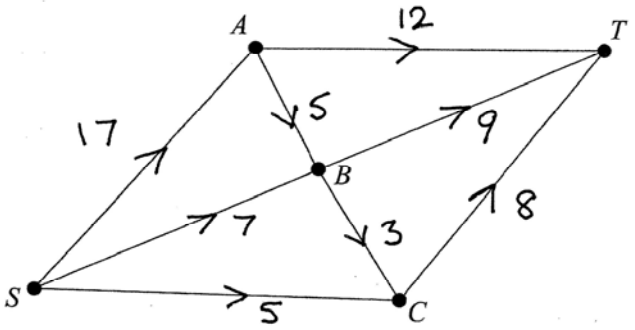
MD02

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

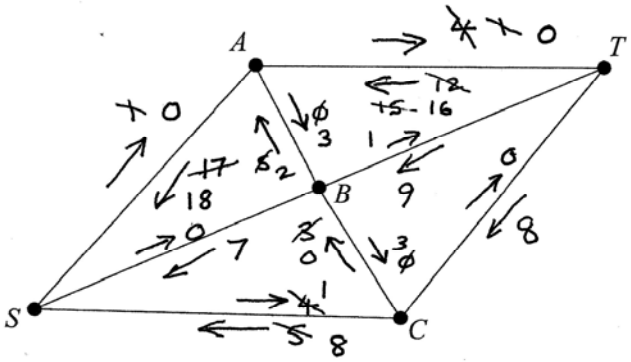
Q	Solution	Marks	Total	Comments
6(a)(i)	18 +(0+) 10 + 3 + 5 (= 36)	B1	1	
(ii)	30 , 32 , 36 (missing cut values)	B3	3	B1 each value correct
(iii)	Max flow = 29 because value of minimum cut is 29	B1 E1	2	Award B0 E1 if their min^{m} cut is < 29 and min^{m} value explained as max flow
(iv)		B1 cao	1	may 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 .....

