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General Certificate of Education (A-level)
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Mathematics MD02

(Specification 6360)

Decision 2

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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Key to mark scheme abbreviations

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

No Method Shown

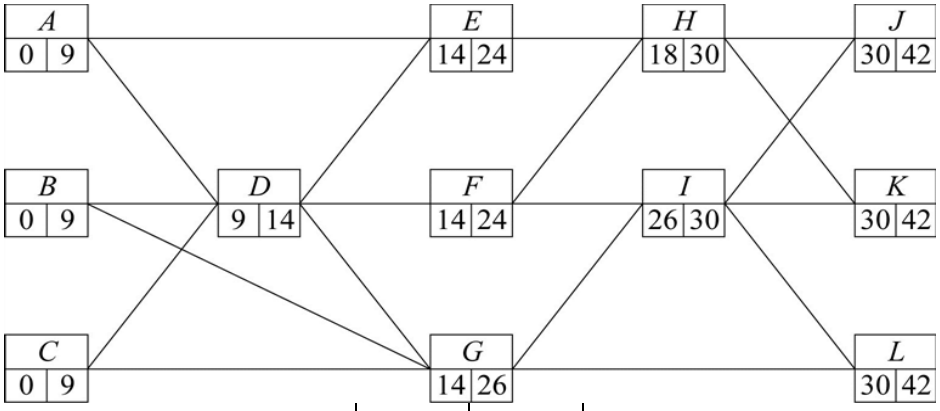
Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

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

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

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

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

Q	Solution	Marks	Total	Comments
1(a)				
		M1		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**	

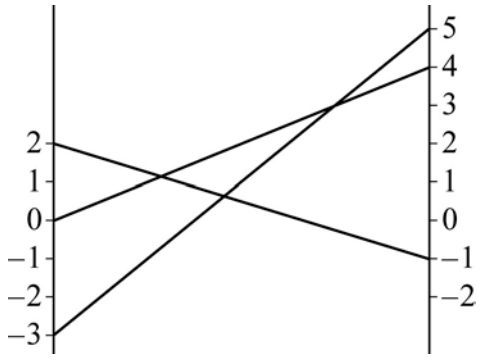
Q	Solution	Marks	Total	Comments
4				

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

Marks	Total	Comments
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
B1	9	Or reverse

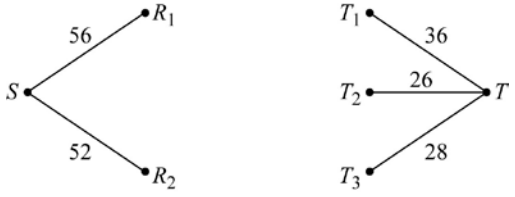
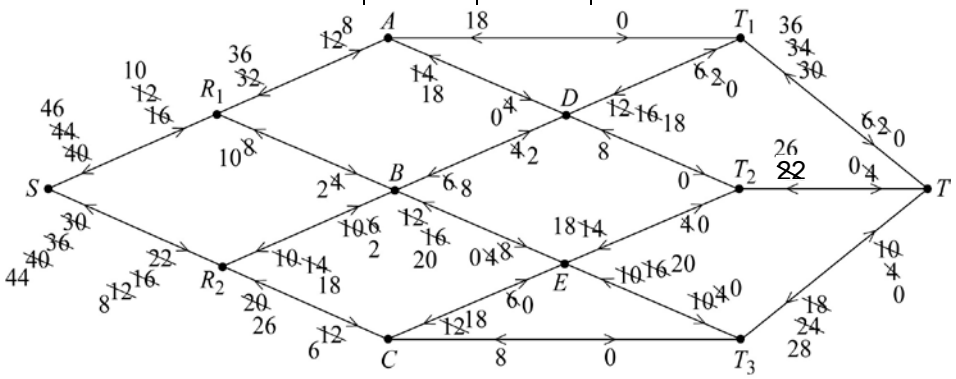
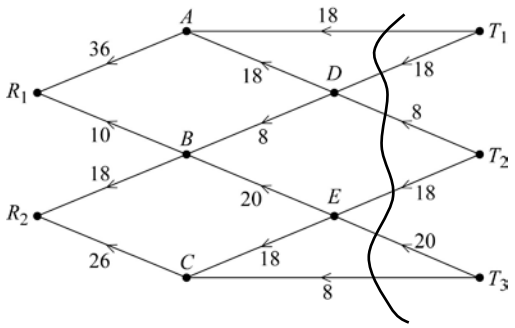
Route *A C G I K*

	Total		**9**

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)	$\begin{array}{cccccccc} P & x & y & z & r & s & t & \text{Value} \\ 1 & -4 & -3 & -1 & 0 & 0 & 0 & 0 \\ 0 & \textcircled{2} & 1 & 1 & 1 & 0 & 0 & 25 \\ 0 & 1 & 2 & 1 & 0 & 1 & 0 & 40 \\ 0 & 1 & 1 & 2 & 0 & 0 & 1 & 30 \end{array}$	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**	