OCR
Oxford Cambridge and RSA

GCE

Mathematics

Unit **4736:** Decision Mathematics 1

Advanced Subsidiary GCE

Mark Scheme for June 2017

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation in scoris	Meaning
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	**Meaning**
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

Here are the subject specific instructions for this question paper

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more ‘method’ steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation ‘dep *’ is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

MARK SCHEME

Question			Answer/Indicative content	Mark	Guidance
1	(i)		After 1st pass 10 3 6 12 4 5 12 After 2nd pass 3 6 10 4 5 12 12 After 3rd pass 3 6 4 5 10 12 12 After 4th pass 3 4 5 6 10 12 12 After 5th pass 3 4 5 6 10 12 12	M1 A1 B1 **[3]**	(Lists may be written vertically) First pass has 12 at right-hand end (even if other values are wrong) (first row or first row after original or identified as pass 1) This list after 3rd pass (even if there were earlier errors) List sorted after 4th pass, 5th pass used to check but no 6th pass
	(ii)	(a)	40 27 8 14 27 40 8 14 Note: given list was 27 8 14 40, this may appear before the answers	B1 B1 **[2]**	This list (first or second) This list (first or second) If more than two lists are given, mark the first two only
		(b)	2	B1 **[1]**	'2 more' Ignore any passes shown, B1 is for stating that there are two (more)

2					**Must be written answers.** Diagrams may support reasoning but get no marks on their own.
	(i)	(a)	The nodes are not all of even order.	B1 **[1]**	It has an odd vertex; it has odd vertices; it has a vertex of order 5 which is odd Need 'odd' (or 'not all even'), not just 'there is a vertex of order 5'
		(b)	Odd nodes occur in pairs so one of the missing values is odd and the other is even, (hence exactly 2 nodes of odd order so semi-Eulerian). OR Total vertex order is even so one more odd node (one odd and one even) (exactly one extra odd) (2 odd nodes altogether)	B1 **[1]**	Using 'even number of vertices with odd vertex order' to deduce that there are 2 odd vertices (or only one of the missing ones is odd), need not explicitly say 'so semi-Eulerian' Not just stating that there must be 2 odd vertices (or that one of the missing ones is odd) (with or without reference to semi-Eulerian) <u>Not for calculating</u> the missing orders 1, 2 or for using total = 16
	(ii)		The sum of the vertex orders = 2 x number of arcs = 16 ⇒ missing orders sum to 3 Simply connected, so vertex order 0 is impossible. Hence missing vertex orders are 1 and 2	M1 A1 **[2]**	**Answer must be labelled as (ii) not credited in (iii)** Sum of orders = 16 or twice number of arcs or sight of 2×8 = 16 or sum of missing orders = 3 or 16 - (2+2+4+5) or 16 - 13 or use reasoning similar to (iii) using vertex of order 5 Not just from a diagram and not from unsupported answers 1 and 2 Missing orders are 1 and 2 (deduced from a complete and correct reasoned argument including simply connected or 16 – 13)
	(iii)		**Given** a simply connected graph vertex orders 5, 4, 2, 2, 2, 1 The vertex of order 5 must be joined to <u>each</u> of the others The order 4 is also connected to the three 2's The order 1 is not connected to any of these The order 2's are not connected to each other Hence, all such graphs have the same structure (are isomorphic)	 B1 M1 A1 **[3]**	**Do not need to explain why these are the vertex orders** Accept other words for 'order' provided intention is obvious Understanding <u>connections</u> for the vertex of order 5 Trying to deal with <u>connections</u> for the other vertices, any one of these three statements or equivalent (e.g. order 4 is connected to three others) Correct argument from a simply connected graph with vertex orders 5,4,2,2,2,1 to only one possible structure

3 (i)

Line	N	P	M	A	B	Display
10	5					
80		0	5			
90				13		
100					12	
110						5, 12, 13

B1 Line 10, $N = 5$
B1 $P = 0$ and $M = 5$ both on second row
M1 $A = 13$ on the next row
A1 $B = 12$ on the following row and stopping after (attempted) display

[4]

Mark entries in columns for the variables: N, P, M, A, B in the row where they first appear
Ignore any row labelled as line 20 or line 60

Ignore values copied down into lower rows
Do not deduce entries from printed display values

(ii)

Line	N	P	M	A	B	Display
10	20					
30		1				
40			20			
50			10			
70		2				
50			5			
90				52		
100					48	
110						20, 48, 52

B1 Line 10, $N = 20$

B1 $P = 1$ with $M = 10$ (second and fourth rows)
B1 $P = 2$ with $M = 5$ (fifth and sixth rows)

M1 $A = 52$ on the next row
A1 $B = 48$ on the following row and stopping after (attempted) display

[5]

Mark entries in columns for the variables: N, P, M, A, B in the row where they first appear
Ignore any row labelled as line 20 or line 60

Ignore values copied down into lower rows
Do not deduce entries from printed display values

(iii)

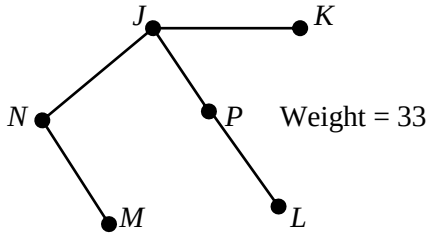
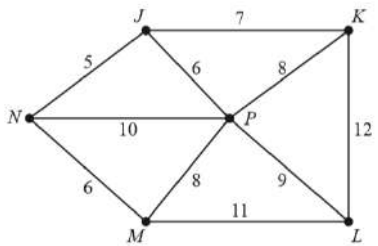
$N = 2^x$ will be repeatedly halved until $M = 1$
and $P = x$

Then $A = 2\times2^{x-1} = 2^x$ (or $A = N$)
and $B = 2^x - 2^x = 0$
The displayed values (for N, B, A) are 2^x, 0, 2^x

M1 Iterate <u>until</u> it = 1, may be from trying a specific case or implied
A1 $P = x$, may be deduced from specific cases but need x here
[$P = x + 1 \Rightarrow$ M1, A0] [$P = x \Rightarrow$ M1, A1]
B1 $A = 2^x$ or $A = N$ (but not $A = 2^P$)
B1 $B = 0$
This B1 B1 may be implied from these displayed values in this form and in this order

[4]

4	(i)		*B* and *E*	B1 **[1]**	Both correct and no others May list vertex orders but need *B* and *E* specifically identified
	(ii)		$A - D - F \quad = 13 + 16 \quad = 29$ $A - E - F \quad = 27 + 8 \quad = 35$ Shortest travel time = 29 minutes	M1 A1 **[2]**	Evidence of considering both $A - D - F$ and $A - E - F$ or sight of both 35 and 29 or mentioning both *D* and *E* 29, after considering <u>both</u> possibilities **SC1** for 29 without showing evidence of considering alternatives
	(iii)		*A* (2, 6; 6) *B* (1, 0;) *C* (5, 19; 19) *D* (3, 7; 7) *E* (8, 24; 33, 24) *F* (7, 23; 23) *G* (6, 20; 20) *H* (4, 18; 18)	M1 M1 dep A1 B1 ft **[4]**	Correct temporary labels (with no extras) at *A*, *C* and *D* (may imply temporary label at *A* if permanent label = 6 but not for *C* and *D*) Some updating of (their) temporary values at *E* <u>only</u> No penalty for crossing out e.g. 33 provided it is evident that a value has been updated in the lower box for *E* (and nowhere else, i.e. no updating at *F*, *G*, *H*) All permanent labels correct (not implied from temporary labels) Order of labelling correct for <u>their</u> permanent labels (using <u>their</u> order gives <u>their</u> permanent labels listed in increasing order) If any permanent label is missing there should be no order label
	(iv)		Total time for direct routes = 222 then repeat *B* to *E* = 24 Total time = 246 minutes Repeated arcs *BC* and *CE* *C* is travelled through 4 times	M1 A1 B1 B1 **[4]**	Attempt at total for <u>half</u> of table i.e. 222 or 444 ÷ 2 246 or 4 hours 6 minutes (cao) [answer 246 o.e. ⇒ M1, A1] Accept $B - C - E$ (correct, not ft) but not e.g. '$B - E$ via C' 4 or 3 + 1 = 4

5	(i)		$P-J-N-M-L-K-P$ $6+5+6+11+12+8=48$ miles	M1 A1 **[2]**	Route starts $P-J-N-M$ 48
	(ii)		e.g. $P-L-M-N-J-K-P$ or $P-M-N-J-K-L-P$ $=46$ miles $=47$ miles	M1 A1 **[2]**	One of these routes, **or in reverse** Correct length (46 or 47) for their route (having achieved M1)
	(iii)		$JN = 5$ $JP = 6$ $MN = 6$ $JK = 7$ ~~$KP = 8$~~ ~~$MP = 8$~~ $LP = 9$ …  Weight = 33	M1 A1 B1 B1 **[4]**	JN may be written as NJ, etc. Need not see individual weights At least five of these seven arcs written listed by increasing order of weight, may have MN before JP and/or MP before KP Not just a list of weights and not from diagram Indicating that KP and MP are not chosen Correct tree 33 (miles)
	(iv)		$k > 9$ LM must be longer than both LP and MN, and the longer of these is $LP = 9$	B1 B1 **[2]**	k greater than 9 (not $k \geq 10$ and not $k \geq 9$) $LP = 9$ and $MN < 9$, need to explicitly refer to both LP <u>and</u> MN (i.e. least weight arc at each end of new arc)
	(v)		Shortest closed route that does not use arc LM is $P-M-N-J-K-L-P$ (or in reverse) $= 47$ miles Shortest route that does use arc LM is $P-L-M-N-J-K-P$ (or in reverse) $= 35 + k$ miles So $35 + k < 47 \Rightarrow k < 12$ (hence $9 < k < 12$) For reference  	M1 M1 A1 **[3]**	(Shortest route without LM has length) 47 (soi) (Shortest route using LM has length) $35 + k$ (soi) $k < 12$ (not $k \leq 11$, not $k = 10, 11$ and not $k \leq 12$) [from either M mark] **SC1** for $k < 12$ (with or without reference to LK) (or as part of a double inequality, e.g. $9 < k < 12$) if neither M mark has been given

6	(i)		$A = (0, 4)$ $B = (0, 2)$ $C = (4, 1)$ $D = (4, 3)$ $E = (3, 5)$	M1 A1 A1 A1 **[4]**	Any one coordinate correct (0, 4) and (0, 2) both correct (4, 1) and (4, 3) both correct (3, 5) correct Ignore not labelling as *A*, *B*, *C*, *D*, *E* or mislabelling
	(ii)		Either checking vertices or using a sliding profit line B (0, 2): $3(0) + 13(2) = 26$ C (4, 1): $3(4) + 13(1) = 25$ [A = 52, D = 51, E = 74] Minimum value is 25	M1 A1 **[2]**	Sight of any $3x + 13y$ for specific numerical values of x, y May be implied from identification of (4, 1) or *C* or from any of these calculations, may be implied from 25 seen with (4, 1) or from 25 indicated in some way as final answer for min value 25 indicated in some way as final answer for min value (www)
	(iii)		New vertex of feasible region where $2x + y = 11$ and $x + 4y = 8$ $\Rightarrow \left(5\frac{1}{7}, \frac{5}{7}\right)$ $3\left(5\frac{1}{7}\right) + 13\left(\frac{5}{7}\right) = 24\frac{5}{7}$	M1 A1 A1 **[3]**	Using <u>these</u> two equations simultaneously (or implied) (5.14, 0.71) (x and y values correct as fractions or to at least 2 dp) 24.7 (correct as a fraction or to at least 3sf) Fractions may be 'top heavy' i.e. $\frac{36}{7}, \frac{173}{7}$
	(iv)		(5, 1) is feasible since $2(5) + 1 = 11$ and $5 + 4(1) = 9 > 8$ But $3(5) + 13(1) = 28 > 25$ [or 26]	B1 B1 **[2]**	Showing that $2x + y \leq 11$ <u>and</u> $x + 4y \geq 8$ at (given point) (5, 1) Numerical evidence (e.g. 11 <u>and</u> 9) not just ticking as checked [Ignore if $-x + 3y \leq 12$ checked] $3x + 13y$ is smaller at (4, 1) [or (0, 2)] than at (5, 1) Sight of 28 (or 15 + 13 or 3(5) + 13) <u>and</u> one of 25, 26, *C* or *B* 28 and reference to their value from part (ii) or (4, 1) [or (0, 2)] oe (i.e. the candidate has said that the value is from part (ii))

<table>
<tr><td>7</td><td>(i)</td><td></td><td>Suppose that the kiln capacity is k, then each dish uses up $\frac{k}{15}$ and x dishes use up $\frac{kx}{15}$ (and similarly for mugs and pots),
so $\frac{kx}{15}+\frac{ky}{50}+\frac{kz}{200}\le k \Rightarrow \frac{x}{15}+\frac{y}{50}+\frac{z}{200}\le 1$
so $40x + 12y + 3z \le 600$
$a = 40$, $b = 12$, $c = 3$ and $d = 600$</td><td>M1
M1
A1
[3]</td><td>Dealing with any of 15, 50 and 200 appropriately (e.g. $x \div 15$ or $15a$, but not $15x$)
An inequality of the form $ax + by + cz \le d$, with numerical coefficients and $b = 4c$, but not necessarily integers
Coefficients 40, 12, 3, 600 or positive integer multiples of these (stated as a, b, c and d or seen in inequality)
$40x + 12y + 3z \le 600$ o.e. (+ integer coefficients) $\Rightarrow$ M1, M1, A1</td></tr>
<tr><td></td><td>(ii)</td><td></td><td>x</td><td>B1
[1]</td><td>cao</td></tr>
<tr><td></td><td>(iii)</td><td></td><td>[z becomes basic and t becomes non-basic]
<table>
<tr><th>P</th><th>x</th><th>y</th><th>z</th><th>s</th><th>t</th><th>u</th><th>v</th><th>RHS</th></tr>
<tr><td>1</td><td>0</td><td>2</td><td>0</td><td>0</td><td>3</td><td>0</td><td>-1</td><td>68</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>2</td><td>0</td><td>-4</td><td>32</td></tr>
<tr><td>0</td><td>0</td><td>2</td><td>1</td><td>0</td><td>4</td><td>0</td><td>-3</td><td>24</td></tr>
<tr><td>0</td><td>0</td><td>6</td><td>0</td><td>0</td><td>28</td><td>1</td><td>-31</td><td>368</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>-1</td><td>0</td><td>1</td><td>4</td></tr>
</table></td><td>B1
M1
M1
A1
[4]</td><td>Correct pivot choice (may be implied from resulting tableau)
Correct structure with all cells filled in, no blanks
5 different basic columns (0's and a single 1)
specifically columns P, x, z (or y) and two of s, t, u
RHS values are all non-negative
P value in RHS column = 68 [dep on both M marks]
Ignore errors in other values provided these conditions are met</td></tr>
<tr><td></td><td>(iv)</td><td>(a)</td><td>0 dishes, 0 mugs and 36 pots
Profit £72</td><td>B1
B1
[2]</td><td>36 <u>pots</u> (in context, may imply 0 dishes and 0 mugs)
£72, with units</td></tr>
<tr><td></td><td>(iv)</td><td>(b)</td><td>May not be able to sell all the pots
Goods may crack in kiln, damaged goods cannot be sold at full price
A particular customer may want a dish or a mug
Demand for dishes, mugs, pots not constant</td><td>B1
[1]</td><td>Any of these or similar
Need to explain why making e.g. 0 dishes, 0 mugs, 36 pots may not generate the £72 that it should
Not discussing slack variables or changing costs (unless it is to take account of e.g. damaged goods)</td></tr>
</table>

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