



Mark Scheme (Results)

Summer 2019

Pearson Edexcel International Advanced Level In
Decision Mathematics D1 (WDM11/01)

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June 2019

Publications Code **WDM11_01_1906_MS**

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if **the candidate's response is not worthy of credit** according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

EDEXCEL GCE MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75.
2. The Edexcel Mathematics mark schemes use the following types of marks:
 - **M marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.**
 - A marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
 - B marks are unconditional accuracy marks (independent of M marks)
 - Marks should not be subdivided.
3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
 - ft – follow through
 - the symbol \surd will be used for correct ft
 - cao – correct answer only
 - cso - correct solution only. There must be no errors in this part of the question to obtain this mark
 - isw – ignore subsequent working
 - awrt – answers which round to
 - SC: special case
 - oe – or equivalent (and appropriate)
 - dep – dependent
 - indep – independent
 - dp decimal places
 - sf significant figures
 - * The answer is printed on the paper
 - \square The second mark is dependent on gaining the first mark
4. **All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.**
 5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.
 6. If a candidate makes more than one attempt at any question:
 - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.

- If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.
7. Ignore wrong working or incorrect statements following a correct answer.

Question Number	Scheme	Marks
1. (a)	NNA: A – D – E – F – B – C – A $27+25+21+34+58+56 = 221$ (km)	M1 A1 A1 (3)
(b)	RMST weight = 118 (km)	B1
	$118 + 27 + 38 = 183$ (km)	M1 A1 (3)
(c)	$183 \leq \text{length} \leq 221$	M1 A1 (2)
		8 marks
Notes for Question 1		
<p>a1M1: Nearest neighbour A – D – E – F – B or accept 1 5 6 2 3 4 across the top of the table a1A1: Route correctly stated, must return to A, accept link back to A a2A1: Length correctly stated. Do not ISW if candidates then go on to double the route length</p> <p>b1B1: CAO for RMST weight (either 118 or $34 + 21 + 25 + 38$) – maybe implied by later working b1M1: Adding $27 + 38$ (the two least weighted arcs) to their RMST length – this mark maybe implied by the correct value for the lower bound – note that their RMST must contain only four arcs b1A1: CAO - if 183 seen without working then award all 3 marks in (b)</p> <p>c1M1: Their answers from (a) and (b) correctly used, accept any inequalities or any indication of an interval from their 183 to their 221 (so $183 - 221$ can score this mark). Please note that $UB > LB$ for this mark c1A1: CAO (no follow through on their values) including correct inequalities or equivalent set notation (but condone $183 < \text{length} \leq 221$)</p>		

Question Number	Scheme	Marks
<p>2. (a)</p>	<p>Route: ABDEFHKJ Length: 76 (km)</p>	<p>M1 A1 (ABCDE) A1 (FGH) A1ft (KJ) A1 A1ft (6)</p>
<p>(b)</p>	<p>Prim: AB, BC; BD, DE</p>	<p>M1; A1 (2)</p>
<p>(c)</p>	<p>Kruskal: FG, JK, FH, not GH, HK, (not HJ), (not FK), (not GJ)</p>	<p>M1; A1 (2)</p>
<p>(d)</p>	<p>Total length: 85 (km)</p>	<p>B1 (1)</p>
<p>11 marks</p>		

Notes for Question 2

In (a) it is important that all values at each node are checked very carefully – the order of the working values must be correct for the corresponding A mark to be awarded e.g. at E the working values must be 24 22 20 in that order (so 24 20 22 is incorrect)

It is also important that the order of labelling is checked carefully – some candidates start with a label of 0 at A (rather than 1) – which is fine. Also the order of labelling must be a strictly increasing sequence – so 1, 2, 3, 3, 4, ... will be penalised once (see notes below) but 1, 2, 3, 5, 6, ... is fine. Errors in the final values and working values are penalised before errors in the order of labelling

a1M1: A larger value replaced by a smaller value in at least two of the working value boxes at either C or E or J or K

a1A1: All values in A, B, C, D and E correct and the working values in the correct order at C and E (including order of labelling). Condone lack of 0 in A's working value

a2A1: All values in F, G and H correct and the working values in the correct order. Penalise order of labelling only once per question (F, G and H must be labelled in that order and F must be labelled after A, B, C, D and E). Note that an additional working value of 56 at H after the 48 is not an error so 48 56 is fine, however, any other number or 56 48 in this order is incorrect and scores A0 in this part

a3A1ft: All values in K and J correct on the follow through and the working values in the correct order. Penalise order of labelling only once per question. To follow through K check that the working value at K follows from the candidate's final values from their feeds into K (which will come from nodes F, H and possibly even J (in the order in which the candidate has labelled them)) and that the final value, and order of

Question Number	Scheme	Marks
	<p>labelling, follows through correctly. Repeat this process for J (which will possibly have working values from G, H and K with the order of these values determined by the candidate's order of labelling at G, H and K)</p> <p>a4A1: CAO - correct route (ABDEFHKJ) not from J to A</p> <p>a5A1ft: Follow through on their final value at J only (so if 76 given as the answer and the final value at J is not 76 then A0)</p> <p>b1M1: First two arcs (AB, BC) chosen correctly in order, or first three nodes (ABC) chosen correctly in order. If any rejections seen at any point, or just a list of all the arcs in order, or only a list of weights then M0 (condone for M1 only those who find the MST for the entire network)</p> <p>b1A1: CSO (must be considering arcs so must be AB, BC, BD, DE or BA, BC, etc.) – do not isw if candidates continue and find the MST for the entire network</p> <p>c1M1: First two arcs (FG, JK) chosen correctly in order and at least one rejection seen at some point – no marks in this part if candidates apply Kruskal to the entire network or if only a list of weights given</p> <p>c1A1: CSO – all selections and rejections correct in the correct order and at the correct time. Note that stating all the arcs in order (e.g. GF, JK, FH, GH, KH, JH, FK, GJ) and then stating only those in the tree in the correct order is fine for both marks in this part</p> <p>d1B1: CAO (85)</p>	

Question Number	Scheme	Marks	
3. (a)	$\frac{132}{42} = 3.14\dots$ so lower bound is 4	M1 A1 (2)	
(b)	Group 1: 8 17 9 7 Group 2: 14 18 10 Group 3: 12 22 Group 4: 15	M1 A1 (2)	
(c)	e.g. middle right 8 17 9 14 18 <u>12</u> 22 10 15 7 17 14 <u>18</u> 22 15 12 8 9 <u>10</u> 7 22 18 17 <u>14</u> 15 12 10 8 <u>9</u> 7 22 18 17 <u>15</u> 14 12 10 9 8 <u>7</u> 22 18 17 15 14 12 10 9 8 7	e.g. middle left 8 17 9 14 <u>18</u> 12 22 10 15 7 22 18 8 17 9 <u>14</u> 12 10 15 7 22 18 <u>17</u> 15 14 8 9 <u>12</u> 10 7 22 18 17 15 14 12 8 <u>9</u> 10 7 22 18 17 15 14 12 10 9 <u>8</u> 7 22 18 17 15 14 12 10 9 8 7	M1 A1 A1ft A1 (4)
(d)	Group 1: 22 18 Group 2: 17 15 10 Group 3: 14 12 9 7 Group 4: 8	M1 A1 (2)	
(e)	B(E)C + G(I)H = (11.2 + 14.5) + (8.3 + 17.2) = 51.2* B(F)G + C(EJ)H = (10.3 + 15.2) + (14.5 + 7.5 + 16.2) = 63.7 B(EJ)H + C(EF)G = (11.2 + 7.5 + 16.2) + (14.5 + 4.3 + 15.2) = 68.9 Repeat arcs: BE, CE, GI, HI	M1 A1 A1 A1 (4)	
(f)	Route e.g. ABEBFECEJIFGIGHIHJDCA Length = 227.2 + 51.2 = 278.4 (m)	B1 B1ft (2)	
(g)	Finishing vertex: C Reduction in lengths: 51.2 – (10.3 + 15.2) = 25.7 (m)	B1 B1 (2)	
		18 marks	

Notes for Question 3

PLEASE NOTE NO MISREADS IN THIS QUESTION – MARK ACCORDING TO THE SCHEME AND THE SPECIAL CASE FOR ASCENDING IN PART (c)

a1M1: Attempt to find the lower bound $(132 \pm 22) / 42$ (a value of 3.14 (or better) seen with no working can imply this mark)

a1A1: CSO - correct calculation seen **or** 3.14 followed by 4 – accept 3.1 if correct calculation seen. An answer of 4 with no working scores M0A0

b1M1: First six items placed correctly and at least eight items placed in bins – condone cumulative totals for M1 only (the values in bold)

b1A1: CSO (so no additional/repeated values)

c1M1: Quick sort, pivot, p, chosen (must be choosing middle left or right – choosing first/last item as the pivot is M0). After the first pass the list must read (values greater than the pivot), pivot, (values less than the pivot). **If only choosing one pivot per iteration then M1 only**

c1A1: First pass correct **and** next pivots chosen correctly for the second pass (but the second pass does not need to be correct) – so they must be choosing (if middle right) a pivot values of 18 and 10 for the second pass or (if middle left) a pivot value of 14

Question Number	Scheme	Marks		
	<p>c2A1ft: Second and third passes correct (follow through from their first pass and choice of pivots). They do not need to be choosing a pivot for the fourth pass for this mark</p> <p>c3A1: CSO (correct solution only – all previous marks in this part must have been awarded) including if middle right a fourth pass with the 15 and 7 used as pivots or if middle left a fifth pass with the 8 used as a pivot</p>			
	<p>Sorting list into ascending order in (c)</p> <ul style="list-style-type: none"> If the candidate sorts the list into ascending order and reverses the list in this part then this can score full marks in (c) If the list is not reversed in (c) but stated in ascending or descending order in (d) then remove the last two A marks earned in (c). If the candidate says that the list needs reversing in (c) but does not actually show the reversed list in (c) then remove the last A mark earned Note that if sorting into ascending order then a ‘sort complete’ statement is required – this could be shown by the final list being re-written or ‘sorted’ statement or each item being used as a pivot (which would therefore mean that the final list would have been written twice) BEFORE list is reversed 			
	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> <p>Middle right ascending (requires sort complete statement– see above)</p> <p>8 17 9 14 18 <u>12</u> 22 10 15 7 8 9 <u>10</u> 7 12 17 14 <u>18</u> 22 15 8 <u>9</u> 7 10 12 17 <u>14</u> 15 18 22 8 <u>7</u> 9 10 12 14 <u>17</u> <u>15</u> 18 22 7 8 9 10 12 14 15 17 18 22</p> </td> <td style="width: 50%; vertical-align: top;"> <p>Middle left ascending (requires sort complete statement – see above)</p> <p>8 17 9 14 <u>18</u> 12 22 10 15 7 8 17 9 <u>14</u> 12 10 15 7 18 22 8 9 <u>12</u> 10 7 14 <u>17</u> 15 18 22 8 <u>9</u> 10 7 12 14 <u>15</u> <u>17</u> 18 22 <u>8</u> 7 9 10 12 14 15 17 18 22 7 8 9 10 12 14 15 17 18 22</p> </td> </tr> </table>	<p>Middle right ascending (requires sort complete statement– see above)</p> <p>8 17 9 14 18 <u>12</u> 22 10 15 7 8 9 <u>10</u> 7 12 17 14 <u>18</u> 22 15 8 <u>9</u> 7 10 12 17 <u>14</u> 15 18 22 8 <u>7</u> 9 10 12 14 <u>17</u> <u>15</u> 18 22 7 8 9 10 12 14 15 17 18 22</p>	<p>Middle left ascending (requires sort complete statement – see above)</p> <p>8 17 9 14 <u>18</u> 12 22 10 15 7 8 17 9 <u>14</u> 12 10 15 7 18 22 8 9 <u>12</u> 10 7 14 <u>17</u> 15 18 22 8 <u>9</u> 10 7 12 14 <u>15</u> <u>17</u> 18 22 <u>8</u> 7 9 10 12 14 15 17 18 22 7 8 9 10 12 14 15 17 18 22</p>	
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	<p>d1M1: First six items placed correctly and at least eight items placed in bins – condone cumulative totals for M1 only (the values in bold)</p> <p>d1A1: CSO (so no additional/repeated values)</p>			
	<p>e1M1: Correct three pairings of the correct four odd nodes (B, C, G and H)</p> <p>e1A1: Any one row correct including pairings and totals</p> <p>e2A1: All three rows correct including pairings and totals</p> <p>e3A1: CAO correct arcs clearly stated: BE, CE, GI and HI – must be these arcs and not e.g. BEC, GIH, or BC via E, etc.</p>			
	<p>f1B1: Any correct route (checks: 21 vertices, starting and ending at A, BE, CE, GI and HI appearing twice, A(2), B(2), C(2), D(1), E(3), F(2), G(2), H(2), I(3), J(2))</p> <p>f2B1ft: For 227.2 + their smallest repeat out of a choice of at least two totals seen in (e) – this mark is dependent on M1 in (e)</p>			
	<p>g1B1: CAO (C)</p> <p>g2B1: CAO (25.7) – note that the correct answer can come from incorrect working e.g. $11.2 + 14.5 = 25.7$ is B0 (just adding BE and EC together) so this answer need to be checked carefully – correct method is $51.2 - (10.3 + 15.2)$ (subtracting BF and FG from 51.2) but give bod on a correct answer of 25.7 with no working</p>			

Question Number	Scheme	Marks
4.(a)(i)	The dummy from event 2 to event 3 is required because activity F (or G) relies on activity A and B but activity D (or E) relies on activity A only	B1
(ii)	The dummy from event 6 to event 7 is required as otherwise activities J and K (which both begin at event 4) would end at the same event	B1 (2)
(b)		M1 A1 M1 A1 (4)
(c)	Minimum completion time: 26 (hours) Critical activities: A, D, I and M	B1 B1 (2)
(d)	The early event time at event 7 is (the larger of) 12 or 9 + x The late event time at event 7 would then be either 15 or 9 + x	M1 A1 A1 (3)
(e)	x = 10	B1 (1)
Notes for Question 4		12 marks

In (a) any use of the terms ‘activity’ and ‘event’ must be correct

ai1B1: CAO dependency - all relevant activities must be referred to - activities A and B and one of D or E and one of F or G (so four activities) must be mentioned

aii1B1: CAO uniqueness – please note that, for example, ‘so that activities can be defined uniquely’ is not sufficient to earn this mark. There must be some mention of describing activities in terms of the event at each end. However, give bod on statements that imply that an activity begins and ends at the same event (for this mark candidates do not need to explicitly mention activities J and K)

b1M1: All top boxes complete, values in the top boxes generally increasing in the direction of the arrows (‘left to right’), condone one ‘rogue’ value (if values do not increase in the direction of the arrows then if one value is ignored and then the values do increase in the direction of the arrows then this is considered to be only one rogue value)

b1A1: CAO for the top boxes

b2M1: All bottom boxes complete, values generally decreasing in the opposite direction of the arrows (‘right to left’), condone one rogue. Condone missing 0 and/or their 26 (at the end event) for the M only

b2A1: CAO for the bottom boxes

c1B1: CAO (26)

c2B1: CAO (A, D, I and M only)

Question Number	Scheme	Marks
di1M1:	One of 12 or $9 + x$ as the early event time for event 7	
di1A1:	Both correct answers 12, $9 + x$ (A0 if 'linked' in some way e.g. $12 > 9 + x$ but bod for the M mark)	
dii2A1:	Both correct answers of 15, $9 + x$ for the late event time for event 7	
e1B1:	CAO (10)	

Question Number	Scheme	Marks
5. (a)	$5y \leq 3z$	M1 A1 (2)
(b)	The total number of shirts must be at least 250	B1
	At most 20% of all the shirts should be small	M1 A1 (3)
(c)	(Minimise) $6x + 10y + 15z$	B1 (1)
(d)(i)	$z = 150 \Rightarrow x + y \geq 100$	M1
	$y \leq 90$	
	$4x - y \leq 150$	A1
(d)(ii)		B1 B1 B1 B1 (6)
(e)	Correct objective line	B1
	V correctly labelled	B1 (2)
(f)	50 small and 50 medium shirts	B1
	Cost = £3050	B1 (2)
(g)	$x = 50, y = 75 \Rightarrow z \geq 125$ therefore minimum number of large shirts is 125	M1
	This leads to a cost of £2925 which is less than the cost in (f)	A1 (2)
		18 marks

Notes for Question 5

a1M1: Correct method: $5y \square 3z$ where \square is any inequality or equals. An exact equivalent answer (with or without integer coefficients) can score M1 **or** M1 for $3y \leq 5z$ only

a1A1: CAO (or equivalent e.g. $k(5y \leq 3z)$ where k is any positive integer only)

b1B1: CAO or e.g. the minimum number of shirts is 250 is fine for this mark (note that they must imply that the total number (and not one particular brand of shirt) is **at least** 250)

b1M1: Three of 'at most', '20%', 'all' and 'small' (allow equivalents e.g. fifth or 0.2 for 20%) allow those who imply 'all' provided that it is clear that they aren't talking about one particular brand only

b1A1: CAO (o.e. e.g. the number of small shirts is less than or equal to a fifth of the total number of shirts, the number of small shirts is at most 20% of all the shirts sold) – give bod of these that clearly imply 'all' provided that they aren't talking about only one particular brand. Do not allow statements which contain use of 0.2 or $\frac{1}{5}$ for this mark, e.g. the number of small shirts is at most 0.2 of all the shirts is A0

Question Number	Scheme	Marks
	<p>c1B1: Expression correct (or $600x + 1000y + 1500z$)</p> <p>di1M1: Eliminating z from all their inequalities by using the substitution $z = 150$ – accept unsimplified (e.g. $x + y + 150 \geq 250, x \leq 0.2(x + y + 150)$ and their $5y \leq 3(150)$)</p> <p>di1A1: CAO e.g. $x + y \geq 100, 4x \leq y + 150, 5y \leq 450$ (oe) - all constraints must be correct with integer coefficients but allow positive multiplies – ignore $x \geq 0, y \geq 0$ but any other additional constraints is A0 – allow recovery in this part if $y \leq 90$ (oe) seen in (d) even if their $5y \leq 3z$ is incorrect in (a)</p> <p>In (d), lines must be long enough to define the correct feasible region and would pass through one small square of the points stated:</p> <p>$x + y = 100$ must pass within one small square of its intersection with the axes – (0, 100) and (100, 0) $y = 90$ must pass within one small square of its intersection with the y-axis and (60, 90) $4x - y = 150$ must pass within one small square of (37.5, 0) and (60, 90)</p> <p>dii1B1: Any one line correctly drawn dii2B1: Any two lines correctly drawn dii3B1: All three lines correctly drawn dii4B1: Region, R, correctly labelled – not just implied by shading – dependent on scoring the three previous B marks in this part</p> <p>e1B1: Drawing the correct objective line on the graph with gradient of -0.6. Line must be correct to within one small square if extended from axis to axis. If line is shorter than (0, 6) to (10, 0) then B0 e2B1: V correctly labelled – note that this mark is dependent on the correct feasible region in (d) (so must have scored at least B1B1B1B0) and the previous B mark in (e)</p> <p>f1B1: CAO – must be in context (50 small and 50 medium and not for $x = y = 50$) note that this mark is dependent on the correct feasible region in (d) (so must have scored at least B1B1B1B0 in (d)) and the first B mark (for a correct objective line) in (e) f2B1: CAO (3050) – units not required - note that this mark is dependent on the correct feasible region in (d) (so must have scored at least B1B1B1B0 in (d)) and the first B mark (for a correct objective line) in (e) – condone if stated/seen in (g)</p> <p>g1M1: Substitute to obtain the correct value for z of 125 (accept $z \geq 125$ or $>$) – if no method allow 125 seen but M0 if 125 found but a different value of z stated and subsequently used g1A1: Correct cost (2925) and dependent on the final B mark in (f)</p>	

Question Number	Scheme	Marks
6.(a)		M1 A1 A1 A1 A1 (5)
(b)	Critical path: A – E – K	B1 (1)
(c)	First critical path: C – H – I – M Second critical path: C – H – I – L	B1 B1 (2)
		8 marks

Notes for Question 6

Condone lack of, or incorrect, numbered events throughout. ‘Dealt with correctly’ means that the activity starts from the correct event but need not necessarily finishes at the correct event, e.g. ‘F dealt with correctly’ requires the correct precedences for this activity, i.e. A, B and C labelled correctly and leading into the same node and F starting from that node but do not consider the end event for F. **Activity on node is M0**

If an arc is not labelled, for example, if the arc for activity G is not labelled (but the arc is present) then this will lose the second A mark and the final (CSO) A mark – they can still earn the third A mark on the bod. If two or more arcs are not labelled then mark according to the scheme. Assume that a solid line is an activity which has not been labelled rather than a dummy (even if in the correct place for where a dummy should be)

Ignore incorrect or lack of arrows on the activities for the first four marks only

a1M1: At least eight activities (labelled on arc), one start and at least two dummies placed

a1A1: Activities A, B, C, first two dummies (+ correct arrows on these two dummies) and D dealt with correctly – the first two dummies are those that meet at the end of activity B

a2A1: Activities E, F, G, H and I dealt with correctly

a3A1: Activities J, K, L and M and 3rd dummy (+ correct arrow on this dummy) dealt with correctly – the 3rd dummy is the one that begins at the end of activity G

a4A1: CSO – Final dummy + arrow, all arrows correctly placed for each activity with one finish and no additional dummies. Note that this is not a unique solution e.g. J and K could be interchanged, or the dummy could come immediately after E, etc. so please check these carefully. **Please check all arcs carefully for arrows – if there are no arrows on dummies then M1 only.**

Note that additional (but unnecessary) ‘correct’ dummies that still maintain precedence for the network should only be penalised with the final A mark if earned

b1B1: CAO (A, E and K only)

c1B1: One correct path (with at most three paths stated)

c2B1: Both correct with no others

