GradeMax

Pearson Edexcel

Mark Scheme (Results)

January 2020

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

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January 2020
Publications Code WDM11_01_2001_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 IAL 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
- ⌐ 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.

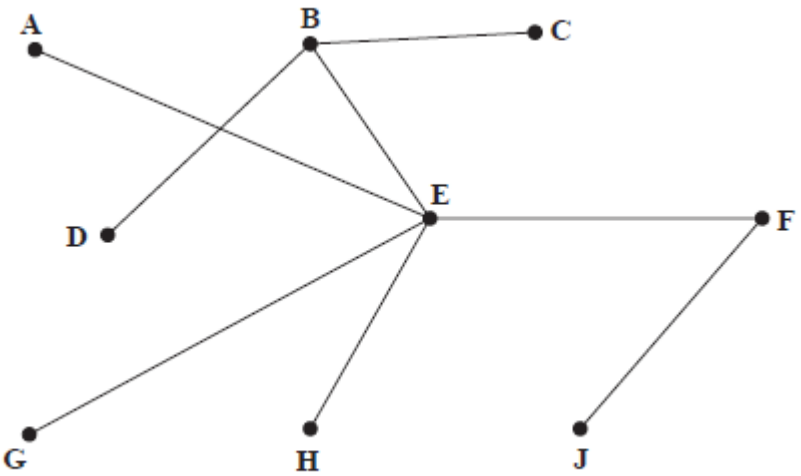
- If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

Question Number	Scheme	Marks
1. (a)	Nearest neighbour: A – B – F – D – E – C – A 35 31 44 39 53 42 = 244 (km)	M1 A1 **(2)**
(b)	MST with B removed: AC, CD, DF, DE gives a RMST weight of 172 (km)	B1
	172 + 31 + 35 = 238 (km)	M1 A1 **(3)** **5 marks**
	Notes for Question 1	

a1M1: Nearest neighbour A – B – F – D – E – C – (condone lack of return to start) **or** correct route length of 244. Accept AB, BF, FD, DE, EC but do not accept weights only. Accept 1 2 6 4 5 3 across the top of the table
a1A1: CAO both route (either in terms of vertices (ABFDECA) or arcs (AB, BF, FD, DE, EC, CA) but not weights) **and** length correct (244) do not ISW if this value is then doubled to 488

b1B1: CAO for RMST weight (either 172 or 42 + 47 + 44 + 39) – maybe implied by later working
b1M1: Adding 31 + 35 (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 238 seen without working then award B0M1A1

Question Number	Scheme	Marks
2. (a)(i)	A tree is a connected graph with no cycles	B1
(ii)	A minimum spanning tree is a tree that contains all vertices The total length of its arcs is as small as possible	B1 B1 **(3)**
(b)	Kruskal: FJ(11), EG(13), EF(15), EH(17), not GH (18), BC (19), not HJ (20), BD (22), not FH(23), AE (25), BE (29) (not AD, DE, DG, AB, BH)	M1 A1 A1 **(3)**
(c)	 (Weight of the tree is) 151	B1 B1 **(2)**
		8 marks

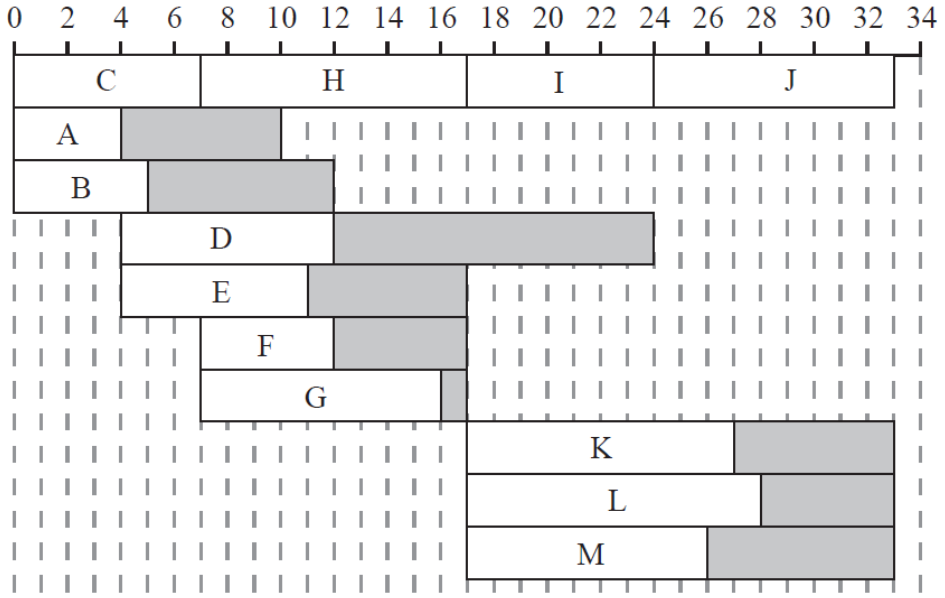
Notes for Question 2

ai1B1: **Connected** + **no cycle(s)** (must contain these two points – do not allow 'circle', 'loop' etc. for cycle(s)) – if not using the word 'connected' then allow 'a graph that connects the vertices/nodes' (condone issues with plural or singular e.g. cycle for cycles)
aii2B1: Contains **all vertices/nodes** (must be clear that all vertices (or nodes) are in a MST)
aii3B1: Total **length** of **arcs** is **minimised** (must contain the three points regarding weight/length, arcs/edges and minimised/smallest (oe))

b1M1: Kruskal's algorithm - first four arcs (FJ, EG, EF, EH) correctly chosen **and** at least one rejection seen at some point
b1A1: All arcs in tree selected correctly in the correct order (FJ, EG, EF, EH, BC, BD, AE, BE) with no additional arcs included in MST
b2A1: CSO including all rejections correct and at the correct time (do not need to see AD, DE, DG, AB, BH rejected but if they are they must be rejected correctly (i.e. in this order) but note that AD, DE have the same weight as do DG and AB so they could appear in either order)

Note that stating all the arcs in order (e.g. FJ, EG, EF, EH, GH, BC, HJ, BD, FH, AE, BE, AD, DE, DG, AB, BH) and then stating only those in the tree in the correct order is fine for all three marks in this part

c1B1: CAO (tree)
c2B1: CAO (151)

Question Number	Scheme	Marks
3.(a)	$x = 8$, $y = 12$, $z = 17$	B3, 2, 1, 0 **(3)**
(b)		M1 A1 A1 A1 **(4)**
(c)	Lower bound is 4 workers e.g. activities J, K, L and M together with $24 < \text{time} < 26$	M1 A1 **(2)**
		9 marks

Notes for Question 3

a1B1: x value correct
a2B1: y value correct
a3B1: z value correct

b1M1: At least ten activities labelled including at least five floats. A scheduling diagram scores M0
b1A1: The critical activities dealt with correctly and appearing just once (C, H, I and J) and three non-critical activities dealt with correctly
b2A1: Any six non-critical activities correct (this mark is not dependent on the previous A mark)
b3A1: CSO – completely correct Gantt chart (exactly thirteen activities appearing just once)

c1M1: Either a statement with the correct number of workers (4) and the correct activities (J, K, L and M) with any numerical time stated **or** the correct number of workers (4) and a time in the interval $24 \leq x \leq 26$ – mark the numerical value only not their use of day/time
c1A1: A completely correct statement with details of both time and activities. Candidates must give a time within the correct interval of $24 < t < 26$. Please note the strict inequalities for the time interval (e.g. implying a time of 24 is incorrect). Answers given as an interval of time are acceptable provided the time interval stated is correct for all its possible values (e.g. time 25 – 26 is A0). Note that 'on day 25' or 'on day 26' are correct but 'on day 24' is not correct. A completely correct statement with an additional incorrect statement scores A0 (so no isw)

Question Number	Scheme	Marks
4. (a)	Bin 1: **35** **17** **7** Bin 2: **10** 28 15 Bin 3: 23 20 Bin 4: 41 Bin 5: 29	**M1** A1 A1 **(3)**
(b)	e.g. middle right	

	35	17	10	7	28	23	41	15	20	29	23
	35	28	41	29	**23**	17	10	7	15	20	41, 7
	41	35	28	29	**23**	17	10	15	20	**7**	28, 15
	41	35	29	**28**	**23**	17	20	**15**	10	**7**	29, 20, (10)
	41	35	**29**	**28**	**23**	**20**	17	**15**	**10**	**7**	Sort complete

		M1 A1 A1ft A1 **(4)**
(c)	Bin 1: **41** 17 Bin 2: **35** **23** Bin 3: **29** **28** Bin 4: 20 15 10 7	**M1** A1 A1 **(3)**
(d)	$8 < x < 12, \quad y > x, \quad (y > 8)$	B3, 2, 1, 0 **(3)**
		13 marks

Notes for Question 4

PLEASE NOTE NO MISREADS IN THIS QUESTION – MARK ACCORDING TO THE SCHEME AND THE SPECIAL CASES IN PART (b) and the guidance for the M mark in (c)

a1M1: First four items placed correctly (the values in bold) and at least seven values placed in bins. Condone cumulative totals for M1 only – if one of the bold values appears in more than one bin then M0
a1A1: First eight items placed correctly (the underlined and bold values) – if one of the underlined values appears in two different bins then this is A0
a2A1: CSO (correct solution only – so no additional/repeated values)

b1M1: 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**
b1A1: First two passes correct
b2A1ft: Third pass correct (follow through from their second pass and choice of pivots for the third pass (these pivots for the third pass must be either middle left or middle right)
b3A1: CSO (correct solution only – all previous marks in this part **must** have been awarded) including a 'sort complete' - 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)

middle left

35	17	10	7	28	23	41	15	20	29	28
35	41	29	**28**	17	10	7	23	15	20	41, 7
41	35	29	**28**	17	10	23	15	20	**7**	35, 23
41	**35**	29	**28**	**23**	17	10	15	20	**7**	(29), 10
41	**35**	29	**28**	**23**	17	15	20	**10**	**7**	15
41	**35**	29	**28**	**23**	17	20	**15**	**10**	**7**	17
41	**35**	29	**28**	**23**	20	**17**	**15**	**10**	**7**	Sort complete

Question Number	Scheme	Marks

SC for (b): If using an incorrect list from the start of (b) with only one error (an error is either one missing number, one extra number, two numbers transposed or one incorrect number) then the most they can score is M1A0A1ftA0

Sorting list into ascending order in (b)

- If the candidate sorts the list into ascending order and reverses the list in this part then this can score full marks in (b)
- If the list is not reversed in (b) then remove the last two A marks earned in (b). If the list is reversed at the start of (c) but not in (b) then still remove the last two A marks earned in (b). If the list is in ascending order in (b) award no marks for first-fit increasing in (c). If the candidate says that the list needs reversing in (b) but does not actually show the reversed list in (b) then remove the last A mark earned

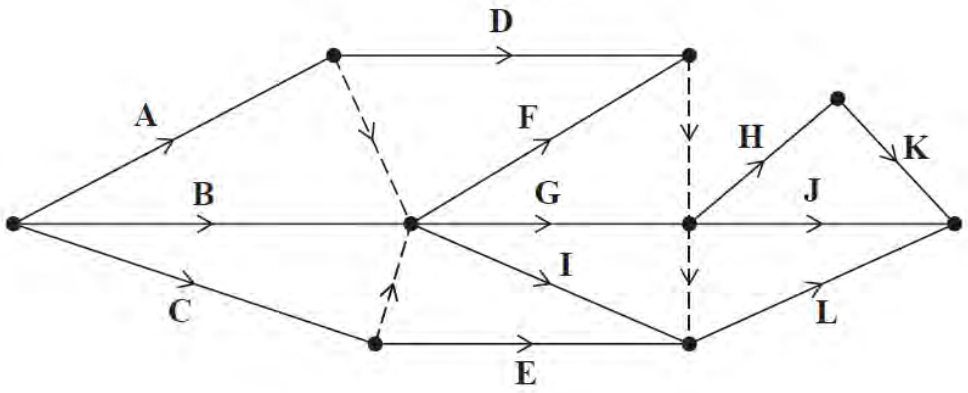
c1M1: **Must be using a list** that is in strictly descending order. If it is clear that their list is not in descending order then M0. First five items placed correctly (the bold values) and at least eight values placed in bins – condone cumulative totals for M1 only – if one of the bold values appears in more than one bin then M0. If it is clear that their list is not correct (41 35 29 28 23 20 17 15 10 7) then M1 only and for this M mark allow them to be using their final list from (b) which can contain one error and in this case an error is either one missing number or one extra number or one incorrect number (e.g. 24 for 23) but their list must be in descending order.
c1A1: First seven items placed correctly (the underlined and bold values) – if one of the underlined values appears in two different bins then this is A0
c2A1: CSO (so no additional/repeated values)

d1B1: $x > 8$
d2B1: $x < 12$

If B0 B0 then award B1 B0 for $8 \leq x \leq 12$ (oe)

d3B1: $x < y$ but not $y > 8$ only

For full marks in (d) no additional incorrect constraints, for example, if B1B1B1 initially awarded but an additional incorrect constraint seen (e.g. $y > 15$) then award B1B1B0 but do not penalise any additional incorrect constraints unless all three other correct constraints seen

Question Number	Scheme	Marks
5. (a)		M1 A1 A1 A1 A1 **(5)**
(b)	Activities E, I, J and L cannot be critical	M1 A1 **(2)**
		7 marks

Notes for Question 5

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. The table below is very useful in checking this point. **Activity on node is M0**

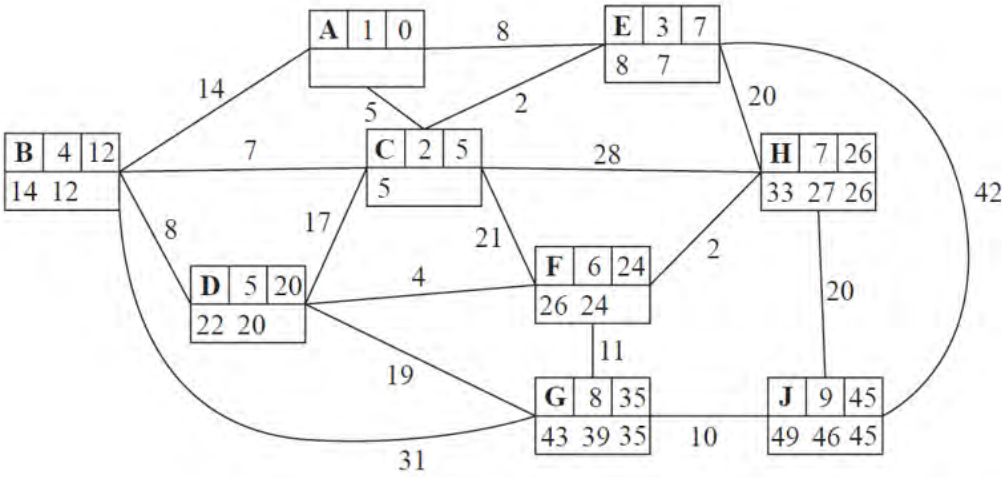
If an arc is not labelled, for example, if the arc for activity E is not labelled (but the arc is present) then this will lose the first A mark and the final (CSO) A mark – they can still earn the second A mark on the bod. If two or more arcs are not labelled then mark according to the scheme. Assume 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: Seven activities (labelled on arc), one start and at least two dummies placed
a1A1: Activities A, B, C, 1st two dummies (including correct arrows on these two dummies), D and E dealt with correctly. The first two dummies are those at the end of activities A and C
a2A1: A dummy linking D, F and G into an event node and a dummy linking D, F, G, I and E into an event node and F, G and I dealt with correctly. The dummies must have arrows
a3A1: Activities H, J, K and L dealt with correctly
a4A1: CSO – all arrows correctly placed for each activity with one finish and at most four dummies. Note that this is not a unique solution due to for example the 3rd and 4th dummies so please check these carefully.
Please check all arcs carefully for arrows – if there are no arrows on any 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

b1M1: At least two correct activities with no more than 5 activities stated
b1A1: All four activities (E, I, J and L) and no others

A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
-	-	-	A	C	A, B, C	A, B, C	D, F, G	A, B, C	D, F, G	H	D, E, F, G, I

Question Number	Scheme	Marks
6. (a)	 Shortest time: 45 (minutes) Quickest route: A C B D F G J	M1 A1 (CEBD) A1 (FH) A1ft (GJ) A1ft A1 **(6)**
(b)	A(CB)D + HJ = 20 + 20 = 40 A(CBDF)H + D(FG)J = 26 + 25 = 51 A(CBDFG)J + D(F)H = 45 + 6 = 51 Repeated arcs: AC, BC, BD, HJ	M1 A1 A1 A1 A1 **(5)**
(c)(i) **(ii)**	Vertex C: 4 times Vertex D: 3 times	B1 B1 **(2)**
(d)	H to H requires the consideration of the shortest path from A to J only (as these are the only two odd nodes) 314 > 309 or 45 > 40 so quicker to start at H and finish at D	B1 B1 **(2)**
		15 marks

Notes for Question 6

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 J the working values must be 49 46 45 in that order (so 49 45 46 is incorrect)

It is also important that the order of labelling is checked carefully. 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 any node except A or C

a1A1: All values at C, E, B and D correct and the working values in the correct order (including order of labelling)

a2A1: All values at F and H correct and the working values in the correct order. Penalise order of labelling only once per question (F and H must be labelled in that order and F must be labelled after C, E, B and D)

a3A1ft: All values in G 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 G check that the working value at G follows from the candidate's final values from their feeds into G (which will mostly likely come from nodes B, D and F (in the order in which the candidate has labelled them)) and that the final value, and order of labelling, follows through correctly. Repeat this process for J (which will possibly have working values from E, H and G with the order of these values determined by the candidate's order of labelling at E, H and G)

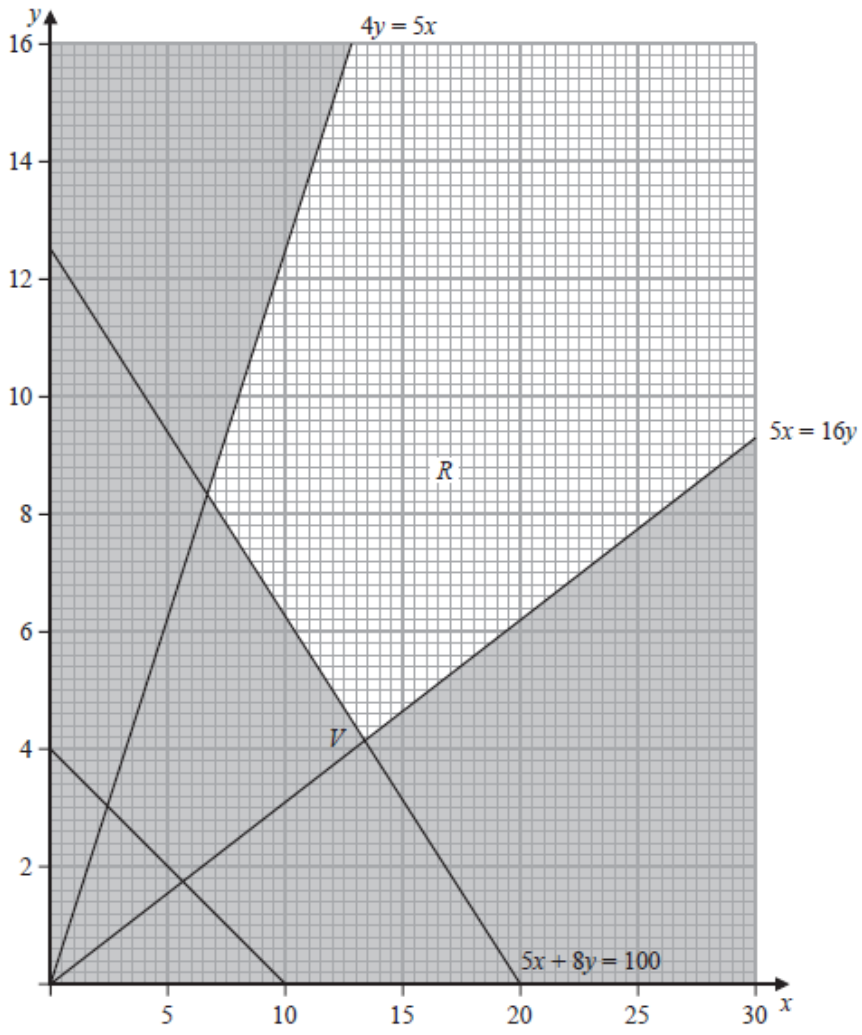
Question Number	Scheme	Marks

a4A1ft: Follow through on their final value at J **only** (condone lack of units) - so if 45 given as the answer and the final value at J is not 45 then A0
a5A1: CAO - correct route (from either A to J or J to A) – ACBDFGJ or JGFDBCA

b1M1: Correct three distinct pairings of the correct four odd nodes A, D, H and J
b1A1: **Any** row correct including pairing **and** total
b2A1: **Any** two rows correct including pairings **and** totals
b3A1: **All** three rows correct including pairings **and** totals
b4A1: CAO correct edges clearly stated and not just in their working as AC, BC, BD, HJ. Must be these arcs and not AD, ACBD or AD via B and C

ciB1: CAO (Vertex C: 4)
ciiB1: CAO (Vertex D: 3)

d1B1: Correct reasoning (that to travel from H to H) only the shortest path between A and J needs traversing twice – as a minimum must mention either 'A to J only' or refer to A and J being the only odd nodes (e.g. odd nodes: A and J is fine but not 'A and J are odd nodes')
d2B1: Either 'it will be slower' or 'it will be quicker from H to D' (if saying 'quicker' then it must be clear that they are talking about H to D) + correct numerical argument (not just stating the values 314 and 309 (or 45 and 40) and saying 'slower' - there must be some comparison of these two values)

Question Number	Scheme	Marks
7. (a)	Minimise $400x + 550y + 750z$ Subject to $x + y + z \geq 20$ $x \leq 2(y + z)$ $z \leq \frac{1}{4}(x + y + z) \Rightarrow 3z \leq x + y$	B1 B1 M1 A1 M1 A1 **(6)**
(b)(i)(ii)	Ratio of 5:3 $\Rightarrow 3y = 5z$ $x + y + z \geq 20 \Rightarrow x + y + \frac{3}{5}y \geq 20$ and $400x + 550y + 750\left(\frac{3y}{5}\right)$ $5x + 8y \geq 100$ and $400x + 1000y$	B1 M1 A1 **(3)**
(c)		B1 B1 B1 B1 **(4)**
(d)	Drawing an objective line accept reciprocal gradient Correct objective line V correctly labelled	M1 A1 A1 **(3)**
(e)(i) **(ii)**	Cost is £9800 3 days for senior leaders (12 training days for new teachers, 5 days for middle leaders)	B1 B1 **(2)**
		18 marks

Question Number	Scheme	Marks

Notes for Question 7

a1B1: Expression correct <u>together</u> with 'minimise' or 'min' but not 'minimum' – isw if coefficients are subsequently simpified but $400x + 550y + 750z$ must be seen at some point for this mark to be awarded. The 'min' must appear beside the correct expression
a2B1: CAO ($x + y + z \geq 20$)

a1M1: $x \square 2(y+z)$ where $\square$ is any inequality or equals. Accept $2x \leq y + z$ for this mark

a1A1: CAO $x \leq 2(y+z)$ or equivalent but only one term in each variable and integer coefficients

a2M1: $z \square \frac{1}{4}(x+y+z)$ where $\square$ is any inequality or equals – allow 0.25 but do not allow

$z \square 25\%(x+y+z)$ unless recovered to a fraction or decimal later

a2A1: CAO $3z \leq x + y$ or equivalent but only one term in each variable and integer coefficients

bi1B1: Ratio expressed correctly as an equation $3y = 5z$ (oe) (possibly implied by subsequent working)
bii1M1: Their linear equation in y and z only (must be of the form $ay = bz$ oe) substituted into their constraint and their objective to eliminate z **or** one correct answer simplified
b1A1: CAO $5x + 8y \geq 100$ and $400x + 1000y$ (allow ISW if correct objective simplified)

In **(c)**

$5x + 8y = 100$ must pass if extended within one small square of its intersection with the axes – (0, 12.5) and (20, 0) but must be long enough to define the correct feasible region
$4y = 5x$ must pass within one small square of its intersection with the origin and (10, 12.5)
$5x = 16y$ must pass within one small square of its intersection with the origin and (20, 6.25)

c1B1: One line correct
c2B1: Two lines correct
c3B1: All three lines correct
c4B1: Region, *R*, correctly labelled – not just implied by shading – dependent on scoring the first three marks in this part

d1M1: Drawing their objective line (based on their answer to (b)) or its reciprocal - line must be correct to within one small square if extended from axis to axis. If their line is shorter than (0, 1) to (2.5, 0) then M0
d1A1: Drawing a **correct** objective line subject to the conditions above regarding length and if extended from axis to axis
d2A1: V labelled clearly on their graph (so dependent on the first three marks in (c) and the previous A mark in this part)

eiB1: CAO – condone lack of units – dependent on the first three marks in (c) and the first two marks in (d)
eiiB1: CAO (3) – dependent on the first three marks in (c) and the first two marks in (d)

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