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Mark Scheme (Results)

January 2017

Pearson Edexcel
International A-Level Mathematics

Decision Mathematics 1 (WDM01)

GradeMax

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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
- ⌐ 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.	$\left\lceil \frac{1+10}{2} \right\rceil = 6$ Noether – reject 6 – 10 $\left\lceil \frac{1+5}{2} \right\rceil = 3$ Gauss – reject 1 – 3 $\left\lceil \frac{4+5}{2} \right\rceil = 5$ Lagrange – reject 5 $\lceil 4 \rceil = 4$ Hamilton (reject 4) Hilbert <u>not</u> in list	M1 A1 A1 A1cso **(4)** **4 marks**

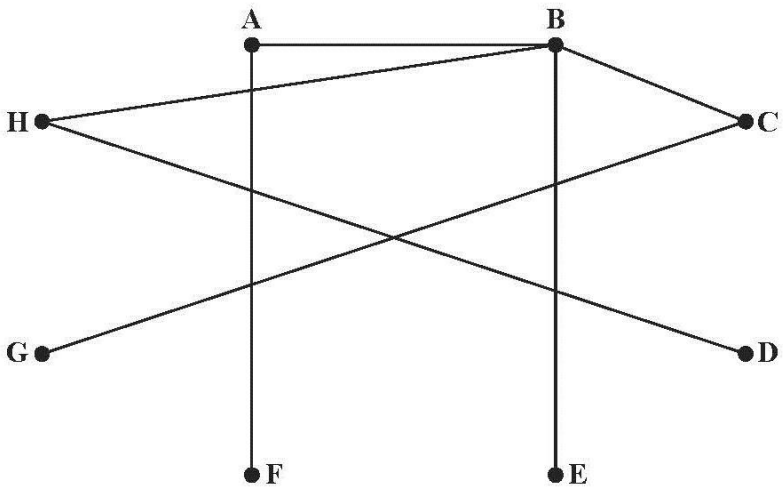
Notes for Question 1

1M1: Choosing middle right pivots (choosing middle left is M0) + an attempt at discarding/retaining half the list

1A1: First pass correct i.e. 6th item **and** using 1 – 5 in the second pass (must not be using the 6th item in the second pass)

2A1: Second and third passes correct i.e. 3rd (G) and 5th (L) items (no sticky pivots) – need not be rejecting the 5th item for this mark

3A1: CSO search complete (so rejecting 5th and 4th items (which in the case of the 4th item may be implicit)) + 'not found' – must be a clear distinction between Hamilton and Hilbert

Question Number	Scheme	Marks
2. (a)	AF, AB, BE; BC, CG; BH, DH	M1; A1; A1 **(3)**
(b)		B1 **(1)**
(c)	Weight of tree = 178 (mins)	B1 **(1)** **5 marks**

Notes for Question 2

a1M1: First three arcs correctly chosen in order (AF, AB, BE, …) **or** first four nodes correctly chosen in order (A, F, B, E, …). **If any rejections seen at any point then M1 (max) only**. Order of nodes may be seen on the top of the table {1,3,-,-,4,2,-,-}. If only the weights of the arcs are stated then withhold this mark

a1A1: First five arcs correctly chosen in order (AF, AB, BE, BC, CG, …) **or** all eight nodes correctly chosen in order (A, F, B, E, C, G, H, D). Order of nodes may be seen on the top of the table {1,3,5,8,4,2,6,7} – do not condone any missing numbers so, for example, the 8 must be above D

a2A1: CSO – all **arcs** correctly **stated** and chosen in the correct order. Candidates must be considering arcs for this final mark (do not accept a list of nodes or numbers across the top of the table unless the correct list of arcs (in the correct order) is also seen)

Misread: Starting at a node other than A scores M1 only – must have the first three arcs (or four nodes or four numbers) correct (and in the correct order) – condone any rejections seen for this mark

b1B1: CAO (condone lack of weights on arcs)

c1B1: CAO (condone lack of units)

For reference: AF(23), AB(27), BE(20), BC(24), CG(26), BH(28), DH(30)

Question Number	Scheme	Marks
3. (a)	Alternating path: A – 6 = D – 2 = C – 5 = F – 4 Change status: A = 6 – D = 2 – C = 5 – F = 4 Improved matching: A = 6, B = 1, C = 5, D = 2, (E unmatched), F = 4	M1 A1 A1 **(3)**
(b)	e.g. A is only allocated to task 6 (so A must do task 6), so D must therefore be matched to task 2 (as D can only be allocated to tasks 2 and 6) which leaves E without a match (as E can only be allocated to task 2) – so there are three workers that can only do two tasks	B1 **(1)**
(c)	Alternating path: E – 2 = D – 6 = A – 1 = B – 3 or E – 2 = D – 6 = A – 1 = B – 5 = C – 3 Change status: E = 2 – D = 6 – A = 1 – B = 3 or E = 2 – D = 6 – A = 1 – B = 5 – C = 3 Complete matching: A = 1, B = 3, C = 5, D = 6, E = 2, F = 4 or A = 1, B = 5, C = 3, D = 6, E = 2, F = 4	M1 A1 A1 **(3)** **7 marks**

Notes for Question 3

a1M1: An alternating path from A to 4 (or vice-versa)
a1A1: CAO – a correct path including change status **either** stated **or** shown. Chosen path clear
a2A1: CAO (improved matching) must follow from the correct stated path. Accept on a clear diagram (with five arcs only)

b1B1: for this mark tasks/workers must be referred to explicitly by number/letter – the two most common arguments are those that state that there are three workers (A, D and E) that can **only** do two tasks (2 and 6) or there are four tasks (1, 3, 4 and 5) that can **only** be done by three workers (B, C and F). For example,

- A can only do 6, D can only do 2 and 6, and E can only do 2 – B1
- A, D and E between them can only do 2 and 6 – B1
- 1, 3, 4 and 5 can only be done by B, C and F – B1
- 2 and 6 can only be done by A, D and E – B0
- B, C and F can only do 1, 3, 4 and 5 – B0
- There are three workers that can only do two tasks – B0
- A can only do 6, E can only do 2 therefore D has no task to do – B0
- A must do 6, E must do 2 so therefore D has no task to do as D can only do 6 and 2 – bod B1

c1M1: An alternating path from E to 3 (or vice-versa)
c1A1: CAO – a correct path including change status stated **or** shown. Chosen path clear
c2A1: CAO (complete matching) must follow from two correct stated paths (so both previous M marks must have been awarded). Accept on a clear diagram (with six arcs only)

Misread: Alternating path from A to 3 in (a) – mark both parts (a) and (c) as a misread (so remove the final two A marks if earned – so can score a maximum of M1A1A1 in (a) and M1A0A0 in (c))

In (a) Alternating path is A – 6 = D – 2 = C – 3 leading to A = 6, B = 1, C = 3, D = 2, (E unmatched), F = 5
In (c) (i) E – 2 = D – 6 = A – 1 = B – 5 = F – 4 or (ii) E – 2 = D – 6 = A – 1 = B – 3 = C – 5 = F – 4
leading to to (i) A = 1, B = 5, C = 3, D = 6, E = 2, F = 4 or (ii) A = 1, B = 3, C = 5, D = 6, E = 2, F = 4

If alternating path in (a) starts from E then send to review

<table>
<tr><th>Question Number</th><th>Scheme</th><th>Marks</th></tr>
<tr><td>4. (a)</td><td>$\frac{178}{45} = 3.95...$ so lower bound is 4 bins</td><td>M1 A1 (2)</td></tr>
<tr><td>(b)</td><td>Bin 1: 23 18
Bin 2: 27 9
Bin 3: 25 10
Bin 4: 12 30
Bin 5: 24</td><td>M1 A1 (2)</td></tr>
<tr><td>(c)</td><td>e.g. (left to right)
<table><tr><td>23</td><td>18</td><td>27</td><td>9</td><td>25</td><td>10</td><td>12</td><td>30</td><td>24</td></tr><tr><td>23</td><td>27</td><td>18</td><td>25</td><td>10</td><td>12</td><td>30</td><td>24</td><td>9</td></tr><tr><td>27</td><td>23</td><td>25</td><td>18</td><td>12</td><td>30</td><td>24</td><td>10</td><td>9</td></tr><tr><td>27</td><td>25</td><td>23</td><td>18</td><td>30</td><td>24</td><td>12</td><td>10</td><td>9</td></tr><tr><td>27</td><td>25</td><td>23</td><td>30</td><td>24</td><td>18</td><td>12</td><td>10</td><td>9</td></tr><tr><td>27</td><td>25</td><td>30</td><td>24</td><td>23</td><td>18</td><td>12</td><td>10</td><td>9</td></tr><tr><td>27</td><td>30</td><td>25</td><td>24</td><td>23</td><td>18</td><td>12</td><td>10</td><td>9</td></tr><tr><td>30</td><td>27</td><td>25</td><td>24</td><td>23</td><td>18</td><td>12</td><td>10</td><td>9</td></tr></table>List in order</td><td>M1
A1
A1ft
A1cso (4)</td></tr>
<tr><td>(d)</td><td>Bin 1: 30 12
Bin 2: 27 18
Bin 3: 25 10 9
Bin 4: 24
Bin 5: 23</td><td>M1 A1 (2)</td></tr>
<tr><td>(e)</td><td>e.g. 5 of the suitcases are over 22.5 (half the weight of a container). No two of these five can be paired in a bin, so at least 5 bins will be required.</td><td>B1 (1)
11 marks</td></tr>
<tr><td colspan="3">Notes for Question 4</td></tr>
<tr><td colspan="3">a1M1: Attempt to find the lower bound $(178 \pm 30)/45$ (a value of 3.95 or 3.96 seen with no working can imply this mark)
a1A1: CSO – correct calculation seen or 3.95 or 3.96 followed by 4 – accept 3.9 if correct calculation seen. An answer of 4 with no working scores M0A0

b1M1: First six items placed correctly – condone cumulative totals for M1 only

b1A1: CSO – all correct</td></tr>
</table>

Question Number	Scheme	Marks

c1M1: Bubble sort. Consistent direction throughout sort, end number (greatest/least) in place **and** first pass correct

c1A1: Second and third passes correct – so end three numbers in place

c2A1ft: Fourth and fifth passes correct following through from the candidate's third pass – so end five numbers in place

c3A1: CSO (correct solution only) – including either a 'sort complete' statement (after the seventh pass) or final list rewritten/eighth pass

Sorting list into ascending order in (c)

- If the candidate sorts the list into ascending order and reverses the list in (c) then they can score full marks
- If the list is not reversed then mark as a misread (so remove the last two A marks earned). If the candidate says that the list needs reversing but doesn't actually show the reversed list then remove the final A mark earned

d1M1: Must be using 'sorted' list in descending order. First six items placed correctly. Condone cumulative totals for M1 only

d1A1: CSO – all correct

SC for (d) – if 'sorted' list is incorrect from part (c) and M0 would be awarded in (d) then award M1 only in (d) for their first six items correctly placed – by 'incorrect' they can have only one error, e.g. one missing number, one extra number, or one number incorrectly placed

e1B1: CAO – must have used five bins in (d) - an argument based on the fact that 5 of the suitcases weigh more than half of the maximum weight capacity of a container. Allow mention of > 22 (rather than > 22.5)

right to left in (c)

23	18	27	9	25	10	12	30	24
30	23	18	27	9	25	10	12	24
30	**27**	23	18	25	9	24	10	12
30	**27**	**25**	23	18	24	9	12	10
30	**27**	**25**	**24**	23	18	12	9	10
30	**27**	**25**	**24**	**23**	18	12	10	9

List in order

Question Number	Scheme	Marks
5. (a)	A(FG)C + E(FI)J = 14.5 + 9.2 = 23.7 A(F)E + C(GFI)J = 10.2 + 13.5 = 23.7 A(FI)J + E(FG)C = 9.6 + 14.1 = 23.7 So repeat tracks AF, EF, CG, FG, FI and IJ	M1 A1 A1 A1 A1 **(5)**
(b)	Any route e.g. AFAEFEHIFIKJIJGFGCGDCBA Length = 106.7 + 23. 7 = 130.4 (km)	B1 DB1ft **(2)**
(c)	The new track would make A and C even So only EJ would need to be repeated Extra distance would be 15 + 9.2 = 24.2 > 23.7 So it would increase the total distance (by 0.5 (km))	 B1 B1 **(2)** **9 marks**
	Notes for Question 5	

a1M1: Three distinct pairings of the correct four odd nodes

a1A1: Any one row correct including pairing and total

a2A1: Any two rows correct including pairings and totals

a3A1: All three rows correct including pairings and totals

a4A1: Correct arcs explicitly identified and not just stated in their working. Accept e.g. AFGC but not AC

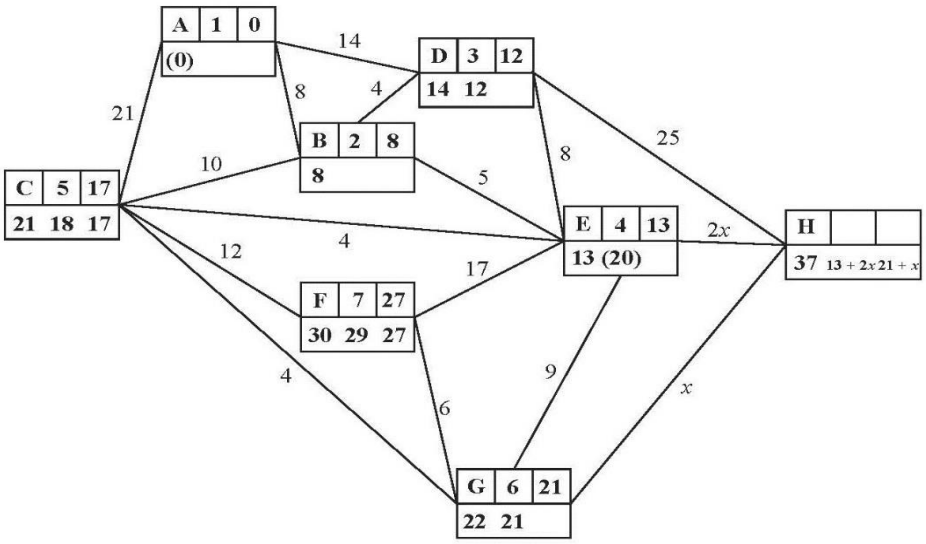
b1B1: Any correct route – checks: starts and finishes at A, 23 vertices, repeats AF, EF, CG, FG, FI and IJ and node A appears 3, B(1), C(2), D(1), E(2), F(4), G(3), H(1), I(3), J(2), K(1)

b2B1ft: 130.4 or 106.7 + ft their least from (a) – this mark is dependent on at least two totals seen in (a)

c1B1: Explicit mention of EJ or EFIJ (not just 9.2) – if any other pairing mentioned then B0

c2B1: 24.2 + 'increase' provided 23.7 found as least in (a) **or** 130.9 + 'increase' provided 130.4 found in (b) **or** 14.5 stated as the length of AC + increase **or** 14.5 compared with 15 + 'increase'. This mark is not dependent on the previous B mark – so B0B1 can be awarded

SC for (c): If B0B0 awarded but 'increase of 0.5' stated then award B1B0

Question Number	Scheme	Marks
6. (a)	 Shortest path from A to H via D: ABDH length: 37 Shortest path from A to H via G: ABECGH length: $21 + x$ Shortest path from A to H via E: ABEH length: $13 + 2x$	M1 A1 (ABDE) A1 (CG) A1ft (FH) A1 A1 A1 **(7)**
(b)	$21 + x + 2 = 13 + 2x$ $x = 10$	M1 A1 **(2)** **9 marks**

Notes for Question 6

In (a) the order of the working values must be correct for the corresponding A mark to be awarded e.g. at F the working values must be 30 29 27 in that order (30 27 29 is incorrect). The order of labelling must also 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 at least once in the working values at either C or D or F or G

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

a2A1: All values C and G correct and the working values in the correct order. Penalise order of labelling only once per question

a3A1ft: All values in F and H correct on the follow through and the working values in the correct order. Penalise order of labelling only once per question. Ignore permanent label and final value at H

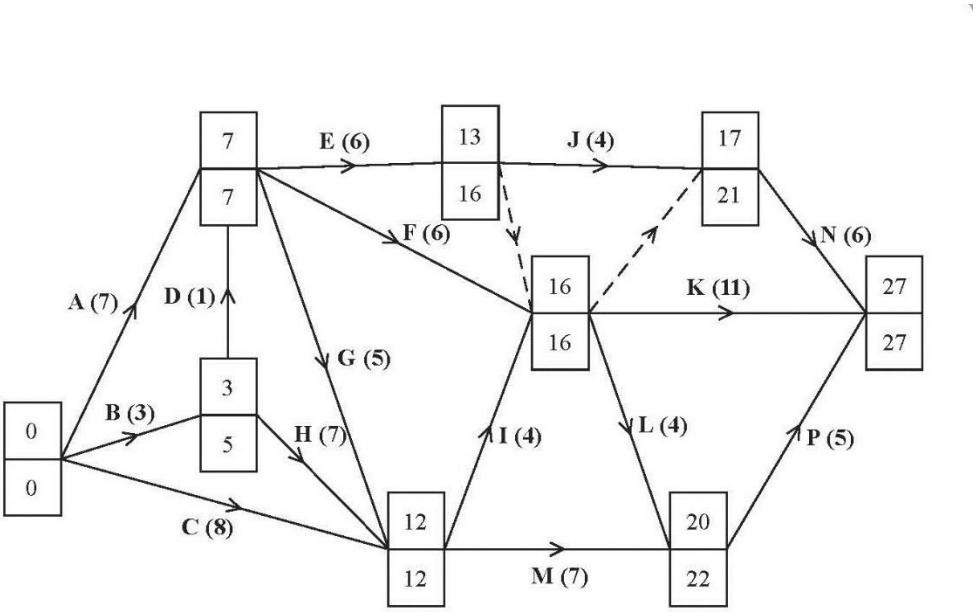
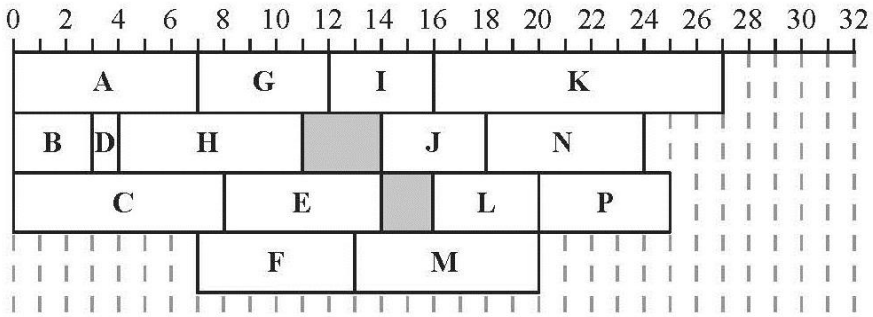
a4A1: ABDH and 37

a5A1: ABECGH and $21 + x$

a6A1: ABEH and $13 + 2x$

b1M1: Their final value from G (their 21) + x + 2 = their final value from E (their 13) + $2x$ – both expressions must be linear in x

b1A1: CAO – if no working seen but $x = 10$ stated together with the correct two working values in x at H then award M1A0

Question Number	Scheme	Marks
7. (a)		M1 A1 M1 A1 **(4)**
(b)	Critical:- e.g. zero float, no delay, immediate, if delayed project will finish late, etc. Path:- e.g. from start event to end event continuously, the event forming end of one activity forms the start of the next, etc.	B1 B1 **(2)**
(c)	Critical path: AGIK	B1 **(1)**
(d)(i) **(ii)**	4 day delay on J – no effect on the project completion date (float on J is 4) 4 day delay on M – project finishes 1 day late (float on M is 3)	B1 B1 **(2)**
(e)	$\frac{84}{27} = 3.111...,$ so a minimum of 4 workers needed	M1 A1 **(2)**
(f)		M1 A1 A1 **(3)** **14 marks**

Question Number	Scheme	Marks

Notes for Question 7

a1M1: All top boxes complete, values generally increasing in the direction of the arrows ('left to right'), condone one 'rogue' value – condone a missing 0 in the first box for the M mark only
a1A1: CAO (top boxes)
a2M1: All bottom boxes complete, values generally decreasing in the opposite direction of the arrows ('right to left'), condone one 'rogue' value – condone a missing 0 in the first box for the M mark only
a2A1: CAO (bottom boxes)

b1B1: CAO for defining 'critical' part
b2B1: CAO for defining 'path' part

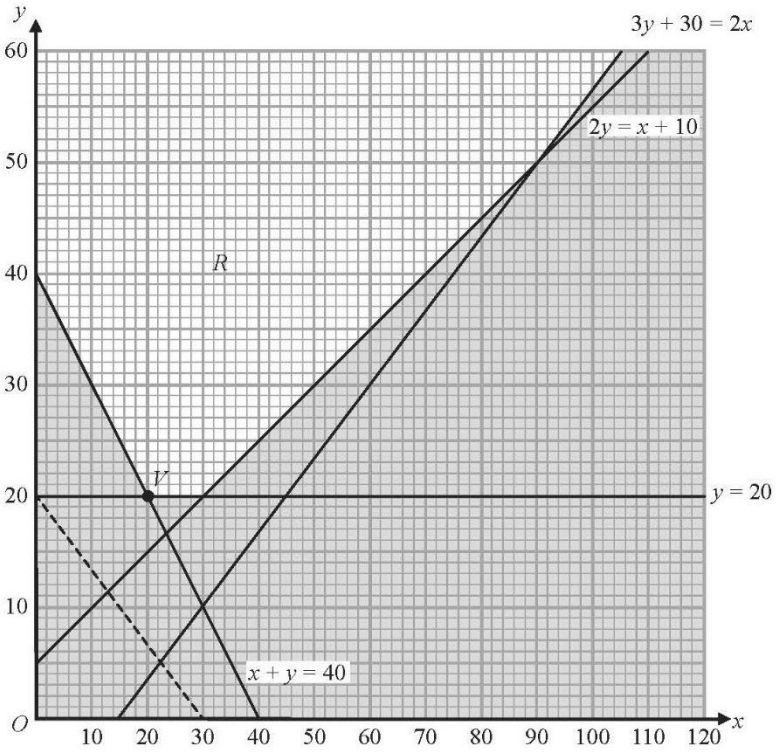
c1B1: CAO (AGIK)

d1B1: CAO – as a minimum accept 'no effect' but not just '0'
d2B1: CAO – as a minimum accept '1 day late' or 'finishes at their 27 + 1' e.g. at time 28 but not just '28'

e1M1: Attempt to find lower bound: (a value in the interval [73 – 95] / their finish time) or (sum of the activities / their finish time) or as a minimum accept awrt 3.1
e1A1: CAO – either a correct calculation seen or awrt 3.1 **then** 4. An answer of 4 with no working is M0A0

f1M1: Not a cascade chart. 4 'workers' used at most and at least 9 activities placed
f1A1: 4 workers. All 15 activities present (just once). Condone at most two errors. An activity can give rise to at most three errors; one on duration, one on time interval and only one on IPA
f2A1: 4 workers. All 15 activities present (just once). No errors

Activity	Duration	Time interval	IPA
A	7	0 – 7	-
B	3	0 – 5	-
C	8	0 – 12	-
D	1	3 – 7	B
E	6	7 – 16	A, D
F	6	7 – 16	A, D
G	5	7 – 12	A, D
H	7	3 – 12	B
I	4	12 – 16	C, G, H
J	4	13 – 21	E
K	11	16 – 27	E, F, I
L	4	16 – 22	E, F, I
M	7	12 – 22	C, G, H
N	6	17 – 27	F, I, J
P	5	20 – 27	L, M

Question Number	Scheme	Marks
8. (a)	Minimise $(P=)2x+3y+5z$ Subject to: $x+y+z\geq 50$ $y\geq 2z$ $\frac{3}{5}(x+y+z)\geq x$ simplifies to $2x\leq 3y+3z$ $\frac{1}{3}(x+y+z)\leq y$ simplifies to $2y\geq x+z$ $(x,y,z\geq 0)$	B1 B1 B1 M1 A1 M1 A1 **(7)**
(b)		B1 B1 B1 B1 **(4)**
(c)	Drawing an objective line accept reciprocal gradient Correct objective line minimum length equivalent to (0, 5) to (7.5, 0) V labelled correctly	M1 A1 A1 **(3)**
(d)	20 ballpoint pens, 20 rollerball pens (and 10 fountain pens) Cost: (£) 150	DB1 DB1 **(2)** **16 marks**

Question Number	Scheme	Marks

Notes for Question 8

a1B1: CAO – expression correct and 'minimise'
a2B1: CAO $(x+y+z \geq 50)$
a3B1: CAO $(y \geq 2z)$

a1M1: Correct method - must see $\frac{3}{5}(x+y+z) \bullet x$ where $\bullet$ is any inequality or =. The bracket must be present or implied by later working
a1A1: CAO – simplified – answer must have integer coefficients $(2x \leq 3y+3z)$ - the correct inequality with no working implies M1A1

a2M1: Correct method – must see $\frac{1}{3}(x+y+z) \bullet y$ where $\bullet$ is any inequality or =. The bracket must be present or implied by later working
a2A2: CAO – simplified – answer must have integer coefficients $(2y \geq x+z)$ - the correct inequality with no working implies M1A1

In (b) lines must be long enough to define the correct feasible region **and** pass through one small 'square' of the points stated in either the horizontal or vertical direction, e.g. for (90, 50) the line must pass through a point in the interval [88, 92] for *x* **or** [49, 51] for *y*:

- $x+y=40$ from (0, 40) to (40, 0)
- $2x-3y=30$ from (30, 10) to (97.5, 55)
- $-x+2y=10$ from (0, 5) to (90, 50)
- $y=20$ from (0, 20) to (90, 20)

b1B1: Any two lines correctly drawn
b2B1: Any three lines correctly drawn
b3B1: All four lines correctly drawn
b4B1: Region, R, correctly labelled – not **just** implied by shading – dependent on scoring the first three marks in this part

c1M1: Drawing the correct objective line or its reciprocal. Line must be correct to within one small 'square' if extended from axis to axis in either the horizontal or vertical direction. If their line is shorter than the length equivalent to that of the line from (0, 5) to (7.5, 0) then M0
c1A1: Correct objective line – same condition that the line must be correct to within one small 'square' if extended from axis to axis in either the horizontal or vertical direction
c2A1: V labelled clearly on their graph. This mark is dependent on all four marks in (b) and the previous A mark in (c). By clearly labelled the vertex should either be labelled 'V' or circled or clearly distinguishable from any other vertex (but A0 if not clear e.g. another vertex circled too)

d1B1: CAO dependent on full marks in (b) and at least M1A1 in (c) – condone no mention of fountain pens – answer must be in context
d2B1: CAO dependent on full marks in (b) and at least M1A1 in (c) - condone lack of units