edexcel

# Mark Scheme (Results)

## Summer 2015

## Pearson Edexcel GCE in Decision Mathematics 1 (6689/01)

GradeMax

**Edexcel and BTEC Qualifications**

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

**Pearson: helping people progress, everywhere**

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Summer 2015
Publications Code UA041213
All the material in this publication is copyright
© Pearson Education Ltd 2015

GradeMax

## 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.

# PEARSON 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)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - $*$ The answer is printed on the paper or ag- answer given
   - $\lfloor$ or d… 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)** | There are two unmatched vertices in each set (the algorithm matches only one vertex from one set to one vertex in the other set once per iteration) | B1 **(1)** |
| **(b)** | B – 4 = C – 5<br>D – 2 = A – 3 = F – 6 = E – 1 | M1<br>A1 **(2)** |
| **(c)** | A = 3, (B unmatched), C = 4, D = 2, E = 5, F = 6 | B1 **(1)** |
| **(d)** | Alternating path: B – 4 = C – 5 = E – 1<br>Change status: B = 4 – C = 5 – E =1<br>Complete matching: A = 3, B = 4, C = 5, D = 2, E = 1, F = 6 | <br>M1<br>A1 **(2)**<br>**6 marks** |
| | **Notes for Question 1** | |

a1B1: CAO – an understanding that there are **two unmatched vertices** in **each set**. However, be generous, and see below examples that we would accept for B1

- Both B and D (or 1 and 5) are unmatched
- Two vertices in set X (or two in set Y) are unmatched
- There are four unmatched nodes (or there are more than two unmatched nodes)
- There are two pairs of nodes that are not matched (on one side of the graph)
- There are two vans (or deliveries) that are not matched to deliveries (or vans)
- There are two vertices on the left (or two on the right) that have not been matched
- Two vertices in set X and Y are unmatched (bod)

Examples for B0:

- There are two unmatched nodes
- There are two sets of unmatched nodes
- Ther are two unmatched arcs in each set

So accept poor terminology (for example, point for vertex, side for set, etc.) but not incorrect terminology (arc for vertex, etc.) and accept contextualised answers (‘vans’ rather than ‘vertices’)

b1M1: One correct alternating path (accept any symbol connecting the vertices, for example, B – 4 – C – 5, or B4C5). Note that 5 – C = 4 – B and 1 – E = 6 – F = 3 – A = 2 – D (so paths from 5 to B and 1 to D) are fine
b1A1: Both paths correct (isw if more than two paths are stated)

c1B1: CAO – condone lack of B or 1 being stated as unmatched. The improved matching may be stated **or** drawn – do check carefully the top of the second page for the improved matching drawn there. Only accept a clear diagram with exactly five arcs

d1M1: The **correct** alternating path from B to 1 (or vice-versa) **and then either** (i) **or** (ii)

(i) the ‘change status’ **either** stated in words (but only accept ‘change (of) status’ **or** ‘c.s.’ not ‘change state’ etc.) **OR** shown (**all** symbols e.g. (…-…=…-…) **interchanged** (…=…-…=…).
(ii) the correct complete matching either stated **or** drawn – only accept a clear diagram with exactly six arcs – do check carefully the top of the second page for the complete matching drawn there.

d1A1: CAO – all three parts – the correct alternating path **and** the change status either stated **or** shown **and** the complete matching either stated **or** drawn

| Question Number | Scheme | Marks |
|---|---|---|
| **2.(a)** | e.g. using middle right<br>18 29 48 9 42 **31** 37 24 27 41 pivot 31<br>18 29 **9** 24 27 31 48 42 **37** 41 pivots 9, 37<br>9 18 29 **24** 27 31 37 48 **42** 41 pivots 24, 42<br>9 18 24 29 **27** 31 37 41 42 48 pivot(s) (18), 27, (41), (48)<br>9 18 24 27 29 31 37 41 42 48 sort complete (pivot (29)) | M1 (quick)<br>A1 (1st pass/pivots for 2nd pass)<br>A1ft (2nd/3rd passes and pivot(s) for 4th pass)<br>A1 (cso + sort complete) **(4)** |
| **(b)** | e.g. left to right 72 53 89 91 68 67 90 77 83 75<br>(end of 1st pass): 53 72 89 68 67 90 77 83 75 **91**<br>(end of 2nd pass): 53 72 68 67 89 77 83 75 **90 91**<br>(end of 3rd pass): 53 68 67 72 77 83 75 **89 90 91**<br>(end of 4th pass): 53 67 68 72 77 75 **83 89 90 91**<br>(end of 5th pass): 53 67 68 72 75 **77 83 89 90 91** sort complete | M1 (bubble)<br>A1 (1st and 2nd passes)<br>A1ft (3rd and 4th passes)<br>A1 (cso + sort complete) **(4)** |
| **(c)** | Pivot 1 = $\left[\frac{1+20}{2}\right]$ = 11 number 53 68 is after 53 so reject 1 - 11<br>Pivot 2 = $\left[\frac{12+20}{2}\right]$ = 16 number 77 68 is before 77 so reject 16 – 20<br>Pivot 3 = $\left[\frac{12+15}{2}\right]$ = 14 number 72 68 is before 72 so reject 14 – 15<br>Pivot 4 = $\left[\frac{12+13}{2}\right]$ = 13 number 68 – number found | M1<br>A1<br>A1(cso) **(3)**<br>**11 marks** |
| | **Notes for Question 2** | |

a1M1: Quick sort, pivot, p, chosen (must be choosing middle left or right – **choosing first/last item as pivot is M0**) and first pass gives <p, p, >p. So after the first pass the list should read (values less than the pivot), pivot, (values greater than the pivot). **If only choosing one pivot per iteration M1 only**
a1A1: First pass correct **and** next pivot(s) chosen correctly for second pass (but second pass does not need to be correct)
a2A1ft: Second and third passes correct (follow through from their first pass and choice of pivots) – **and** next pivot(s) chosen correctly for the fourth pass
a3A1: CSO (correct solution only – all previous marks in this part **must** have been awarded) including 'sort complete' – this could be shown by the final list being re-written or 'sorted' statement or each item being used as a pivot

b1M1: Bubble sort. Consistent direction, end number (greatest/least) in place. Do check these carefully as

| Question Number | Scheme | Marks |
|---|---|---|

some candidates show the result of each comparison and swap in the first pass
b1A1: First and second passes correct – so end two numbers in place
b2A1ft: Third and fourth passes correct following through from the candidate's second pass
b3A1: CSO (correct solution only) – including either a 'sort complete' statement **or** final list rewritten/sixth pass
c1M1: Choosing middle right pivot (choosing middle left is M0) + discarding/retaining half the list. So 53 (the 11th value) found as a pivot and either rejecting the first 11or 10 values or retaining the final 9 or 10 values
c1Al : First and second passes correct i.e. 53 found and either using 67 to 91 in 2nd pass or discarding 9 to 53 (so therefore no 'sticky' pivots in the first two passes — sticky is when the pivot is retained in the next pass). Then 77 found and either using 67 to 75 in 3rd pass or discarding 77 to 91
c2A1 : CSO - search complete + 'found' (accept 'found', 'located', 'stop', etc. but not just, for example, the number underlined; must be convinced that 68 has been located and is not a pivot or a number in a sublist with only one value)

**Sorting list into descending order in either (a) and/or (b)**

- If the candidate sorts the list into descending order and reverses the list 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

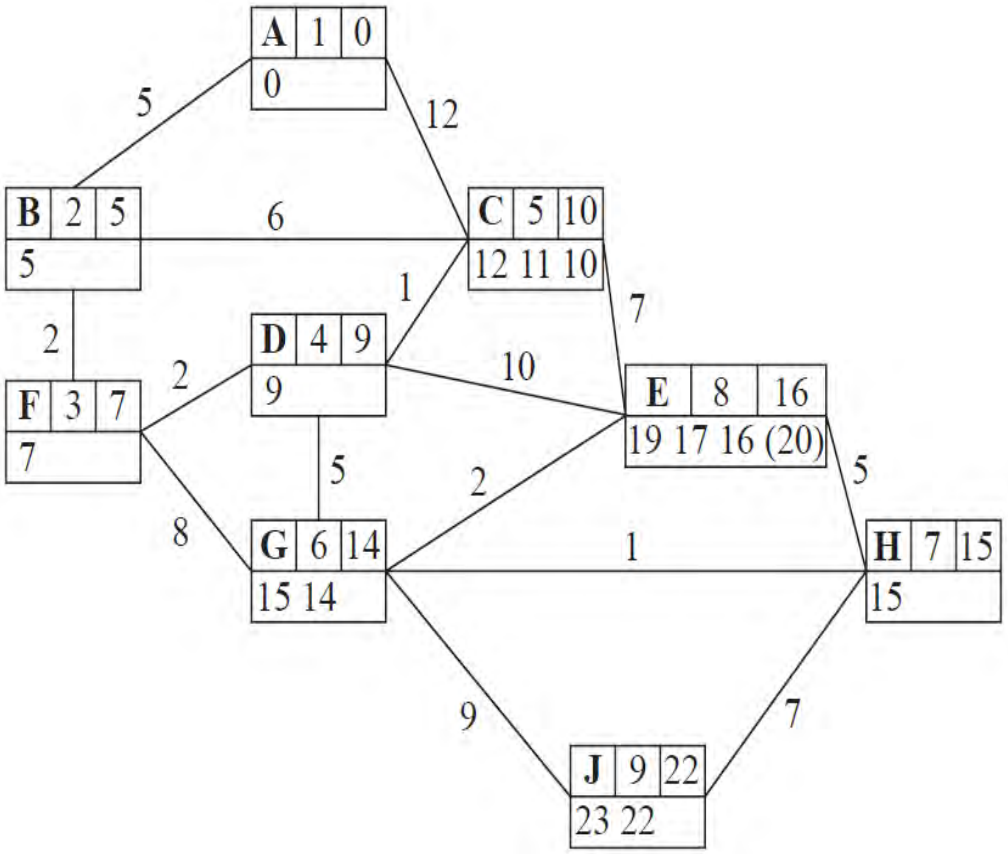
**Misreads** - if there is a 'misread' of a single number (this could take the form of an extra number, a number missing, or a number changed, for example, 13 rather than 31) before starting either sort or the binary search then mark as a misread. If they 'misread' more than one number then M0. If they miscopy one of their own numbers during the sort then this is an accuracy error and loses the corresponding A mark(s)

Using middle left quick sort in (a): (note: for full marks must identify 24 as a pivot but no sort complete statement required as pivoting on the 24 produces no further swaps)

| | |
|---|---|
| 18 29 48 9 [42] 31 37 24 27 41 | pivot 42 |
| 18 29 9 [31] 37 24 27 41 42 48 | pivot(s) 31, (48) |
| 18 29 [9] 24 27 31 [37] 41 42 48 | pivots 9, 37 |
| 9 18 [29] 24 27 31 37 41 42 48 | pivot(s) 29, (41) |
| 9 18 [24] 27 29 31 37 41 42 48 | pivot 24 |
| 9 18 24 27 29 31 37 41 42 48 | (sort complete) |

Right to left bubble sort in (b):

| | |
|---|---|
| | 72 53 89 91 68 67 90 77 83 75 |
| (end of 1st pass): | 53 72 67 89 91 68 75 90 77 83 |
| (end of 2nd pass): | 53 67 72 68 89 91 75 77 90 83 |
| (end of 3rd pass): | 53 67 68 72 75 89 91 77 83 90 |
| (end of 4th pass): | 53 67 68 72 75 77 89 91 83 90 |
| (end of 5th pass): | 53 67 68 72 75 77 83 89 91 90 |
| (end of 6th pass): | 53 67 68 72 75 77 83 89 90 91 (sort complete) |

| Question Number | Scheme | Marks |
|---|---|---|
| **3.(a)** | <br>Shortest route: A – B – F – D – G – H – J<br>Length: 22 (km) | M1<br>A1 (ABFDC)<br>A1 (GH)<br>A1ft (EJ)<br>A1<br>A1ft **(6)** |
| **(b)** | E.g. 22 – 7 = 15 JH, 15 – 1 = 14 HG, 14 – 5 = 9 GD, 9 – 2 = 7 DF, 7 – 2 = 5 FB, 5 – 5 = 0 BA<br>**Or** Trace back from J including arc XY if (Y already lies on the path and) the difference of the final values of X and Y equals the weight of arc XY. | B2, 1, 0 **(2)** |
| **(c)** | Shortest route: A – B – F – D – G – E – G – H – J<br>Length: 26 (km) | B1<br>B1 **(2)**<br>**10 marks** |
| | **Notes for Question 3** | |
| **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 C the working values must be 12 11 10 – in that order (12 10 11 is incorrect).<br>The 20 in brackets in the working values at E is not required but if a candidate does have a value after the 16 then it must be this value only. This value, if present, must also be in the correct place (after the 16). Penalise any other/incorrect working values with the corresponding A mark. Lastly, 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.** | | |

| Question Number | Scheme | Marks |
|---|---|---|

a1M1: A larger value replaced by smaller value at least once in the working values at either C or G or E or J
a1A1: All values in A, B, F, D and C correct. The working values at C must be in the correct order. Condone lack of 0 in A's working value
a2A1: All values in G and H correct and the working values in the correct order. Penalise order of labelling only once per question (G and H must be labelled in that order and G must be labelled after A, B, F, D and C)
a3A1ft: All values in E and J correct on the follow through and the working values in the correct order. Penalise order of labelling only once per question (E and J must be labelled in that order and E labelled after all other nodes (excluding J)). Ignore additional working value of 20 at E – so the working values may read 19 17 16 20 – rather than 19 17 16 – which is fine – however 20 19 17 16 is incorrect and loses this mark

To follow through E check that all the working values at E follow from the candidate's final values from nodes C, D, G and H (in the order that the candidate has labelled these four nodes) and that the final value, and order of labelling, follows through correctly. Repeat this process for J (which will have working values from G and H)
a4A1: CAO for the route (from either A to J or J to A)
a5A1ft: If their answer is not 22 follow through their final value at J (condone lack of units)

For (b) candidates usually give either a general explanation or a demonstration of how they determined their shortest route. If a candidate gives both a general explanation and a demonstration then mark both and award the best mark (but do not mix the two schemes together)

General Explanation:

For the first B mark any indication of 'working backwards' or 'tracing back' through the network – it must be clear from the candidates explanation that they are considering working backwards through the network but give bod for seeing just the phrase 'working backwards' (oe)

For the second B mark we must see

- Working backwards **from J**
- Including an **arc** (XY) if the **difference** of the **final values** (of X and Y) is equal to the **weight** (of the arc XY)

Must include all the words in bold (or their equivalent, for example, distance for weight, edge for node,…) – technical language must be correct

Demonstration:

For the first B mark we must see two consecutive correct calculations working backwards from J for **their** network. They do not have to link the corresponding nodes for this first mark, for example, 22 – 7 = 15, 15 – 1 = 14 is sufficient for this mark (also note that 22 – 15 = 7, etc. is equivalent). Condone poor notation for this mark, for example, 22 – 7 = 15 – 1 = 14… is fine for B1

For the second B mark we must see all the correct calculations (so no follow through) from J to A **and** the linking of **all** arcs/nodes to these calculations, for example, J: 22 – 7 = 15 H, H: 15 – 1 = 14 G, etc. is acceptable. **All** values (including the 22 and 0) **and** nodes (including J and A) must be present

c1B1: CAO shortest route (A – B – F – D – G – E – G – H – J)
c2B1: CAO correct length (26) – condone lack of units

| Question Number | Scheme | Marks |
|---|---|---|
| **4.(a)** | e.g. (each arc contributes 1 to the orders of two nodes, and so) the sum of the orders of all the nodes is equal to twice the number of arcs<br><br>Which implies that the sum of the orders of all the nodes is even and therefore there must be an even (or zero) number of vertices of odd order hence there cannot be an odd number of vertices of odd order. | B1<br><br>B1 **(2)** |
| **(b)** | (Start at) D and (end at) E (or vice-versa) | B1 **(1)** |
| **(c)** | A(C)B + D(BC)E = 120 + 300 = 420<br>A(CB)D + B(C)E = 290 + 130 = 420<br>A(C)E + BD = 150 + 170 = 320*<br>Repeat arcs AC, CE and BD | M1<br>A1 (2 rows)<br>A1 (3 rows)<br>A1 **(4)** |
| **(d)** | Length 2090 + 320 + 130 = 2540 (m) | M1, A1 **(2)** |
| **(e)** | (Finishing Point is) D<br>Difference in routes = 2540 – (2090 + 130 +130 ) = 190 (m) | B1<br>M1, A1 **(3)**<br>**12 marks** |
| | **Notes for Question 4** | |

a1B1: **Either** stating that the sum of the order of the nodes = 2(number of arcs) **or** that each arc contributes 1 to the order of two nodes. For this mark there must be a **clear correct statement linking the order of nodes to arcs**

a2B1: For stating that as the sum (of the orders) of the nodes is even this implies that there must be an even number of nodes of odd order (or there cannot be an odd number of nodes of odd order). Candidates may argue that if the **s**um (of the order) of the nodes is odd then this implies that the number of arcs cannot be integer valued (oe) which is fine. For this mark there must be a correct statement that the **sum of the nodes is even together with the correct conclusion.** Note that for the first B mark it must be clear that the candidate is considering the order of the nodes but for the second B mark it is sufficient to for candidates to say 'the sum of the nodes…'. Furthermore, it is possible to score B0B1 (for example, a candidate may simply state the sum of the nodes is even and state the correct conclusion which would score the 2nd B mark only)

b1B1: Correct start and finish points (D, E)
c1M1: Three distinct pairings of the **correct** four odd nodes
c1A1: **Any** two rows correct including pairings **and** totals
c2A1: **All** three rows correct including pairings **and** totals
c3A1: CAO correct **arcs** clearly (**not** just in their working) stated: AC, CE, BD. Accept ACE **or** AE via C. Do not accept AE
d1M1: 2090 + 130 + (their smallest total from (c)); must be at least two distinct pairings of the correct four odd nodes in (c) **or** for 2410 only (forgetting to add the additional 130)
d1A1: CAO (2540) – if no working seen then the correct answer implies both marks in (d)

e1B1: CAO (D)
e1M1: Their answer to (d) – (2090 + 130 + their BE) (if AB included in (d)) **or** their answer to (d) – (2090 + their BE) (if AB not included in (d)) **or** (their smallest total (320) from (c) – their BE (130)) – by 'their BE' this is their smallest pairing which does not include A. This mark is dependent on **either** scoring the M mark in (c) **or** considering all three pairings (DE, BE, BD) that do not include A
e1A1: CAO (190) – condone lack of units – if the correct answer is seen with no calculation and/or method seen then award the M mark only. Candidates who did not include AB (130) in their inspection route (in (d)) can still earn full marks in (e) for the correct answer of 190

| Question Number | Scheme | Marks |
|---|---|---|
| **5.(a)** | Kruskal: BC, AB, (not AC), DE, CD, DF, (not $\begin{matrix}\text{BF}\\\text{CE}\end{matrix}$), EJ, FH, (not HJ), (not BD), GH | M1 A1 A1 **(3)** |
| **(b)** | Prim: GH, FH, DF, DE; CD, BC; AB, EJ | M1; A1; A1 **(3)** |
| **(c)** | 98 (km) | B1 **(1)** |
| **(d)(i)** | $\frac{m}{2}$ | B1 |
| **(ii)** | $n-1$ | B1 |
| **(iii)** | $m \geq 2(n-1)$ (oe) | B1 **(3)** **10 marks** |
| | **Notes for Question 5** | |

a1M1: Kruskal's – first four arcs BC, AB, DE, CD,…(or weights 6, 7, 10, 11, …) chosen correctly in order and **at least one rejection seen at some point**

a1A1: All eight arcs BC, AB, DE, CD, DF, EJ, FH, GH (or weights 6, 7, 10, 11, 13, 15, 16, 20) chosen correctly in order and no additional arcs

a2A1: CSO All selections and rejections correct (in correct order and at the correct time) – do not accept weights only for this mark

- Listing all the arcs in order and then listing those arcs in the tree in the correct order is fine for **full marks** (this implies that rejections are correct and at the correct time)
- Listing all the arcs in order and just drawing the MST is **M0**

b1M1: First four arcs correctly chosen in order (GH, FH, DF, DE, … or weights 20, 16, 13, 10,…) **or** first five nodes{G, H, F, D, E,…} correctly chosen in order. **If any rejections seen at any point then M1 (max)** only. Order of nodes may be seen at the top of a matrix/table {-, -, -, 4, 5, 3, 1, 2, - }

a1A1: Prim's - first six arcs correctly chosen in order (GH, FH, DF, DE, CD, BC,… or weights 20, 16, 13, 10, 11, 6,…) **or** all nine nodes{G, H, F, D, E, C, B, A, J} correctly chosen in order.. Order of nodes may be seen at the top of a matrix so for the first two marks accept {8, 7, 6, 4, 5, 3, 1, 2, 9} (**no** missing numbers)

a2A1: CSO - all **arcs** correctly **stated** and chosen in the correct order. They must be considering arcs for this final mark (do not accept a list of the weights of each arc, nodes or numbers across the top of the matrix unless the correct list of arcs (in the correct order) is also seen)

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

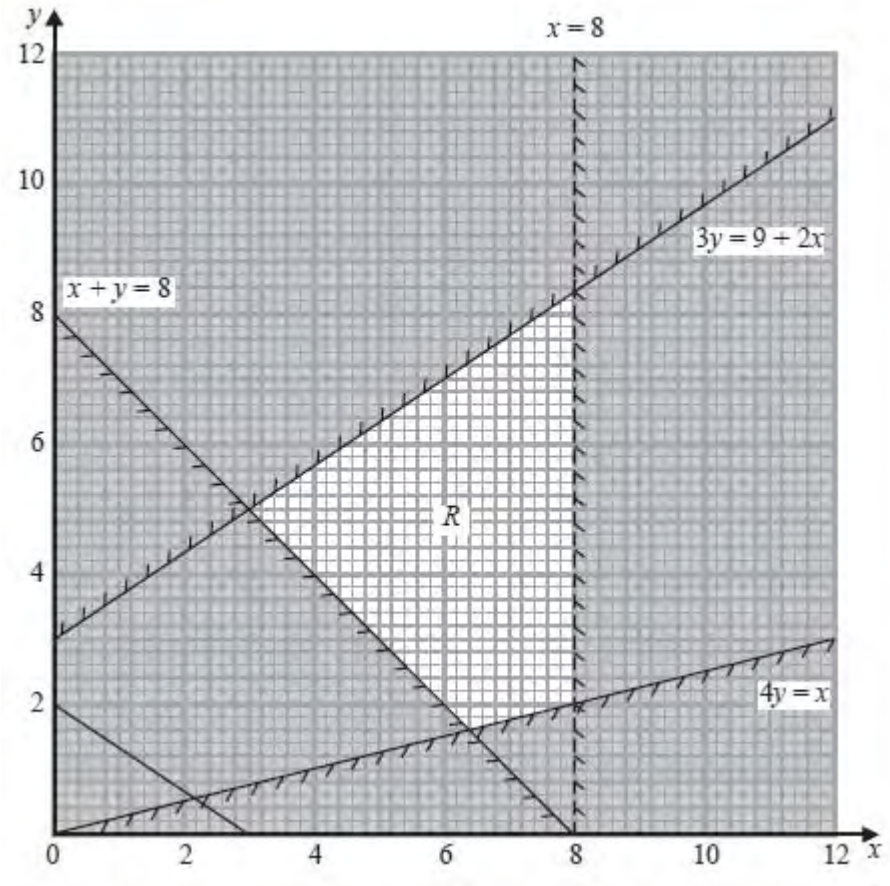
| Starting at | Minimum arcs required for M1 | Nodes | Order |
|---|---|---|---|
| A | AB BC CD DE | ABCDE | 12345---- |
| B | BC AB CD DE | BCADE | 31245---- |
| C | CB AB CD DE | CBADE | 32145---- |
| D | DE CD BC AD | DECBA | 54312---- |
| E | ED CD BC AD | EDCBA | 54321---- |
| F | FD DE CD BC | FDECB | -54231--- |
| H | HF DF DE CD | HFDEC | --5342-1- |
| J | JE DE CD BC | JEDCB | -5432---1 |

c1B1: CAO (98) – condone lack of units

diB1: CAO (oe e.g. 0.5$m$)

diiB1: CAO

diiiB1: CAO (oe, for example, $n-1 \leq \frac{1}{2}m$ ) – must include correct bracketing (if required) – do not accept strict inequality

| Question Number | Scheme | Marks |
|---|---|---|
| **6.(a)** |  | B1 $(x+y=8)$<br>B1 $(3y=9+2x)$<br>B1 $(4y=x)$<br>B1 $(x=8)$ - **must be distinct from the other three lines**<br>**(4)** |
| **(b)** | Correct R labelled | B1 **(1)** |
| **(c)** | Objective line drawn<br>$\mathrm{V}\left(\frac{32}{5},\frac{8}{5}\right)$ (oe) | B1<br>M1 dA1 **(3)** |
| **(d)** | $(C=)\frac{88}{5}$ (oe) | B1 **(1)** |
| **(e)** | (7,7)<br>35 | B1<br>B1 **(2)** |
| **(f)** | $y \leq \frac{5}{3}x \therefore k = \frac{5}{3}$ (oe) | M1 A1 **(2)** |
| | | **13 marks** |

**Notes for Question 6**

**The line $x=8$ must be distinct from the other three lines in some way. Some candidates may show the strict inequality as a solid line and the other three lines as dashed lines – this is acceptable for all four marks in part (a). If a candidate has a mixture of dashed and solid lines (say two of each) then withold the final B mark earned**

a1B1: $x+y=8$ correctly drawn. Must pass within one small square of (0, 8), (4, 4) and (8, 0)

a2B1: $3y=9+2x$ correctly drawn. Must pass within one small square (0, 3), (6, 7) and sufficiently long enough to define the feasible region

a3B1: $4y=x$ correctly drawn. Must pass within one small square of the origin and (8, 2)

a4B1: $x=8$ correctly drawn. Must be sufficiently long enough to define the feasible region. This must be shown as a dashed line or distinctive from the other three lines (see note above)

| Question Number | Scheme | Marks |
|---|---|---|

b1B1: Region, R, correctly labelled – **all lines** must have been drawn correctly but condone $x = 8$ not distinct from the other three lines (so must have scored either B1B1B1B1 or B1B1B1B0 in (a))

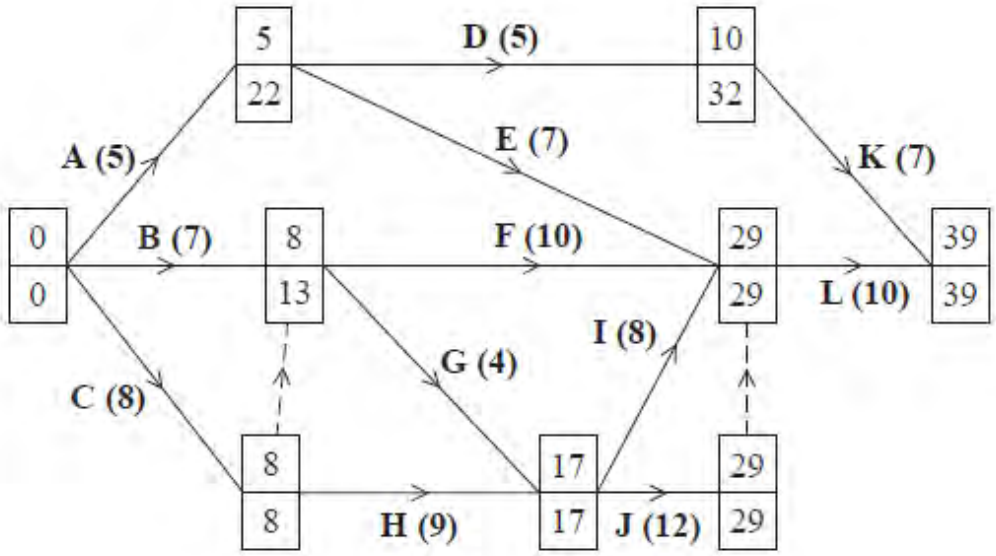
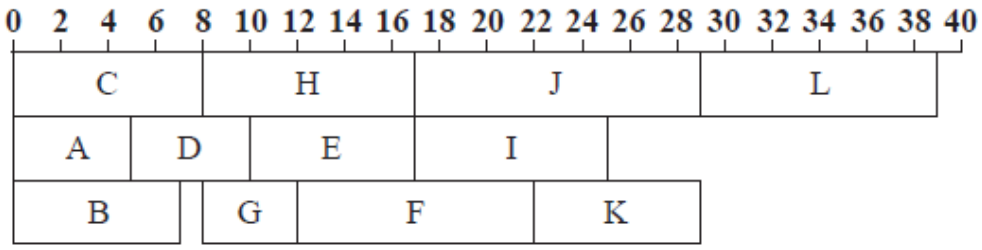
**Note that if no objective line is drawn then no marks in (c)**

c1B1: Drawing a correct objective line – if their line is shorter than the length equivalent to that of the line from (0, 1) to (1.5, 0) then B0. Line must be correct to within one small square if extended from axis to axis
c1M1: Candidates must have drawn either the correct objective line or its reciprocal. If they have drawn the correct objective line they must be solving $x + y = 8$ and $4y = x$. If they have drawn the reciprocal objective line line they must be solving $x + y = 8$ and $3y = 9 + 2x$. Must get to either $x = ...$ or $y = ...$ (condone one error in the solving of the simultaneous equations). The correct exact answer $\left(\frac{32}{5}, \frac{8}{5}\right)$, or for the reciprocal (3, 5), can imply this mark
c1dA1: CAO – the correct exact coordinate $\left(\frac{32}{5}, \frac{8}{5}\right)$ or $(6.4, 1.6)$ or $\left(6\frac{2}{5}, 1\frac{3}{5}\right)$ - this mark is dependent on the correct objective line seen (so must have scored the B mark). If B1 awarded then the correct answer with no working scores M1A1

d1B1: CAO or 17.6 or $17\frac{3}{5}$

e1B1: CAO vertex (7, 7) (accept $x = 7$, $y = 7$)
e2B1: CAO value (35)

f1M1: $(k =)\frac{5}{3}$ or $\frac{3}{5}$ or 1.6 or 0.6 or $1\frac{2}{3}$
f1A1: CAO $(k =)\frac{5}{3}$(oe)

| Question Number | Scheme | Marks |
|---|---|---|
| **7.(a) and (b)** |  | B1<br>B1<br>B1 **(3)**<br><br>M1<br>A1<br>M1<br>A1 **(4)** |
| **(c)** | Lower bound = $\frac{92}{39}$ =2.35… so 3 workers | M1 A1 **(2)** |
| **(d)** | e.g.<br> | M1<br><br>A1<br><br>A1<br><br>A1 **(4)**<br>**13 marks** |
| | **Notes for Question 7** | |

a1B1: Any two of the four arcs (E, F, I or the dummy) drawn correctly (from correct vertex to correct vertex) – activities must be labelled with the correct letter (but condone no weights or arrows) and the dummy must be shown as a dashed line (but condone no arrow)

a2B1: All four arcs (E, F, I and the dummy) drawn correctly – must be labelled with the correct letter (but condone no weight or arrows) and the dummy must be shown as a dashed line (but condone no arrow)

a3B1: CAO – all three activities (E, F and I) and the one dummy drawn correctly – activities must be labelled with the correct letter and the activities and dummy must have the correct arrows (**do check carefully that all arrows are present**) but condone lack of (or incorrect) weights on the activity arcs

**In (b) the M marks are dependent on scoring at least the first mark in (a)**

**In (b) the A marks are dependent on scoring at least the first two marks in (a)**

b1M1: All top boxes complete (condone lack of 0 for the M mark only), values 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 the remaining values do increase in the direction of the arrows then this is considered to be a single rogue value). Note that all values in the top boxes could be incorrect but it can still score the M mark if the values are **increasing** in the way stated above – **this mark is dependent on the first mark having being awarded in (a)**

| Question Number | Scheme | Marks |
|---|---|---|

b1A1: CAO – all values correct in the top boxes – **this mark is dependent on the first two marks having being awarded in (a)**
b2M1: All bottom boxes complete (condone lack of 39 and/or 0 for the M mark only), values generally decreasing in the opposite direction of the arrows ('right to left'), condone one 'rogue' – **this mark is dependent on the first mark having being awarded in (a)**
b2A1: CAO – all values correct in the bottom boxes – **this mark is dependent on the first two marks having being awarded in (a)**
c1M1: Attempt to find lower bound: (a value in the interval [80 – 104] / their finish time) **or** (sum of the activities / their finish time) **or** (as a minimum) an awrt 2.4
c1A1: CSO – either a **correct** calculation seen **or** awrt 2.4 **then** 3. An answer of 3 with no working scores M0A0

d1M1: Not a cascade (Gantt) chart. 4 'workers' used at most and at least 8 activities placed
d1A1: The critical (C, H, J, L) activities and A, B and D correct. A must be completed by its late finish time (22), B must be completed by its late finish time (13) and D must start after A and finish before its late finish time (32)

| Activity | Duration | Time interval | IPA |
|---|---|---|---|
| C | 8 | 0 – 8 | - |
| H | 9 | 8 – 17 | C |
| J | 12 | 17 – 29 | H |
| L | 10 | 29 – 39 | J |
| A | 5 | 0 – 22 | - |
| B | 7 | 0 – 13 | - |
| D | 5 | 5 – 32 | A |

Now check the last 5 activities – the last two marks are for E, F, G, I and K **only**

**First** check that there are only three workers and that all 12 activities are present (just once)

**Then** check precedences (see table below) – each row of the table could give rise to 1 error only in precedences

**Finally** check the length of each activity and the time interval in which the activity must take place (interval is inclusive)

| Activity | Duration | Time interval | IPA |
|---|---|---|---|
| E | 7 | 5 – 29 | A |
| F | 10 | 8 – 29 | B, C |
| G | 4 | 8 – 17 | B, C |
| I | 8 | 17 – 29 | G, H |
| K | 7 | 10 – 39 | D |

d2A1: 3 workers. All 12 activities present (just once). Condone **one** error **either** precedence **or** time interval **or** activity length, on activities E, F, G, I and K only (note: one activity could have more than one error, for example, activity G could have an error in duration and an error in IPA – this is two errors **not** one)
d3A1: 3 workers. All 12 activities present (just once). No errors on activities E, F, G, I and K

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom