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EDEXCEL A LEVEL FURTHER MATHEMATICS: QUESTIONS BY TOPIC

Critical Path Analysis (4)

Decision Mathematics 1 · Topic 4

8 questions · 81 marks · Mark schemes included

Pearson Edexcel A Level Further Mathematics (9FM0), June 2019 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

8 questions · 81 marks · 4 sub-topics



SUB-TOPIC 2.2

SHORTEST PATHS: DIJKSTRA AND FLOYD

Sub-topic 2.2 · 1 question · 10 marks · lowest tariff first



6.

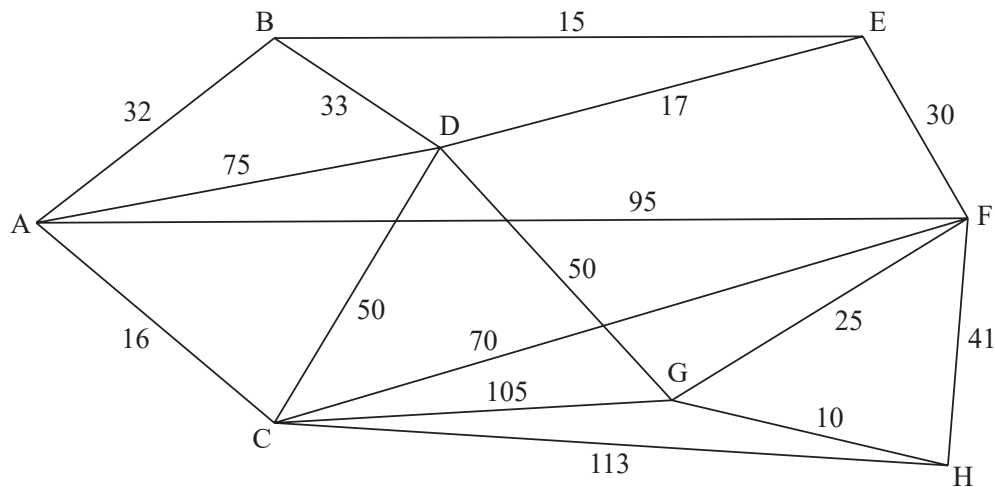


Figure 4

In Figure 4 the weights on the arcs represent distances.

(a) (i) Use Dijkstra's algorithm to find the shortest path from A to H.

(ii) State the length of the shortest path from A to H.

(6)

One application of Dijkstra's algorithm has order n^2 , where n is the number of nodes in the network. A computer produces a table of shortest distances between any two different nodes by repeatedly applying Dijkstra's algorithm from each node of the network.

It takes the computer 0.082 seconds to produce a table of shortest distances for a network of 10 nodes.

(b) Calculate approximately how long it will take, in seconds, for the computer to produce a table of shortest distances for a network with 200 nodes. You must give a reason for your answer.

(3)

(c) Explain why your answer to part (b) can only be an approximation.

(1)

(Total for Question 6 is 10 marks)



7.

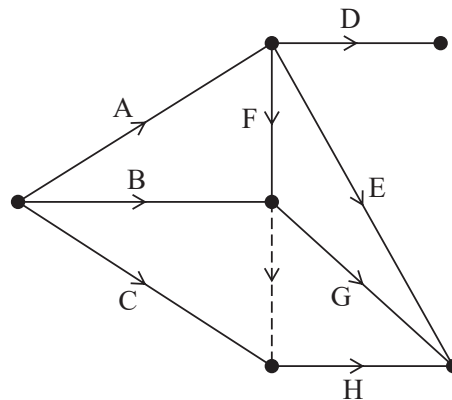


Figure 5

Figure 5 shows a partially completed activity network for a project that consists of 14 activities.

(a) Complete the precedence table in the answer book for the 8 activities in Figure 5.

(2)

The precedence table for the remaining 6 activities is given below.

Activity	Immediately preceding activities
I	D, E, G, H
J	D, E, G, H
K	E, G, H
L	I, J, K
M	J, K
N	J, K

(b) Complete the activity network in the answer book for the project. Your completed activity network must contain only the minimum number of dummies.

(4)

Given that all 14 activities have the same duration,

(c) explain why activity D cannot be critical.

(2)

(Total for Question 7 is 8 marks)



8. Susie is preparing for a triathlon event that is taking place next month. A triathlon involves three activities: swimming, cycling and running.

Susie decides that in her training next week she should

- maximise the total time spent cycling and running
- train for at most 39 hours
- spend at least 40% of her time swimming
- spend a total of at least 28 hours of her time swimming and running

Susie needs to determine how long she should spend next week training for each activity. Let

- x represent the number of hours swimming
- y represent the number of hours cycling
- z represent the number of hours running

- (a) Formulate the information above as a linear programming problem. State the objective and list the constraints as simplified inequalities with integer coefficients.

(5)

Susie decides to solve this linear programming problem by using the two-stage Simplex method.

- (b) Set up an initial tableau for solving this problem using the two-stage Simplex method.

As part of your solution you must show how

- the constraints have been made into equations using slack variables, exactly one surplus variable and exactly one artificial variable
- the rows for the two objective functions are formed

(6)

The following tableau T is obtained after one iteration of the second stage of the two-stage Simplex method.

b.v.	x	y	z	s_1	s_2	s_3	Value
y	0	1	0	1	0	1	11
s_2	0	0	5	-2	1	-5	62
x	1	0	1	0	0	-1	28
P	0	0	-1	1	0	1	11

- (c) Obtain a suitable pivot for a second iteration. You must give reasons for your answer.

(2)

- (d) Starting from tableau T , solve the linear programming problem by performing one further iteration of the second stage of the two-stage Simplex method. You should make your method clear by stating the row operations you use.

(5)

(Total for Question 8 is 18 marks)

TOTAL FOR PAPER IS 75 MARKS



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Please check the examination details below before entering your candidate information

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Time 1 hour 30 minutes**Paper
reference****9FM0/3D****Further Mathematics****Advanced****PAPER 3D: Decision Mathematics 1****Answer book**

Do not return the question paper with the answer book.

Total Marks

Turn over ►

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1.

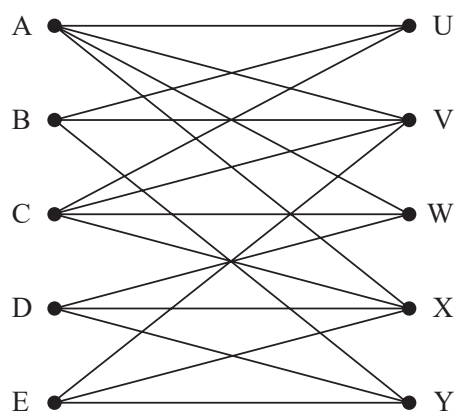


Figure 1



Question 1 continued

(Total for Question 1 is 4 marks)



Key:

Early event time
Late event time

The network diagram shows the following activities and dependencies:

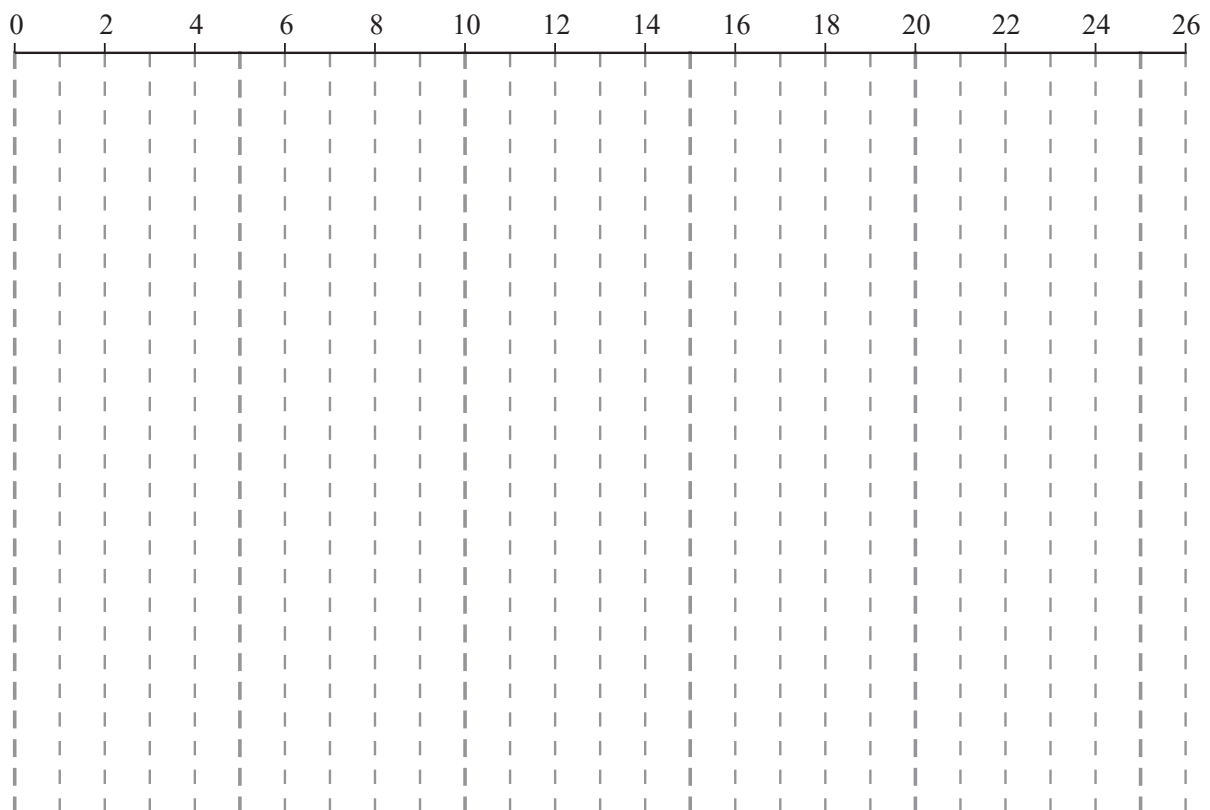
- Activity A(4) leads to B(6) and C(10).
- Activity B(6) leads to D(2) and E(4).
- Activity C(10) leads to F(5).
- Activity D(2) leads to G(6).
- Activity E(4) leads to F(5) and H(7).
- Activity F(5) leads to I(2) and L(7).
- Activity G(6) leads to H(7).
- Activity H(7) leads to J(7).
- Activity I(2) leads to K(6).
- Activity J(7) leads to K(6).
- Activity K(6) leads to L(7) and M(5).
- Activity L(7) leads to M(5).
- Activity M(5) leads to the final node.

Dashed arrows indicate dependencies from the top node of F(5) to the top node of D(2), and from the bottom node of K(6) to the bottom node of L(7).

Diagram 1

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Question 2 continued

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Grid 1

(Total for Question 2 is 9 marks)

3.

	A	B	C	D	E	F	G	H
A	–	24	42	48	34	37	32	22
B	24	–	40	35	30	41	39	44
C	42	40	–	21	26	45	38	36
D	48	35	21	–	32	37	29	27
E	34	30	26	32	–	34	40	28
F	37	41	45	37	34	–	43	41
G	32	39	38	29	40	43	–	38
H	22	44	36	27	28	41	38	–



Question 3 continued

	A	B	C	D	E	F	G	H
A	–	24	42	48	34	37	32	22
B	24	–	40	35	30	41	39	44
C	42	40	–	21	26	45	38	36
D	48	35	21	–	32	37	29	27
E	34	30	26	32	–	34	40	28
F	37	41	45	37	34	–	43	41
G	32	39	38	29	40	43	–	38
H	22	44	36	27	28	41	38	–

(Total for Question 3 is 8 marks)



4. (a)

Initial time matrix

	A	B	C	D	E	F
A						
B						
C						
D						
E						
F						

Initial route matrix

	A	B	C	D	E	F
A	A	B	C	D	E	F
B	A	B	C	D	E	F
C	A	B	C	D	E	F
D	A	B	C	D	E	F
E	A	B	C	D	E	F
F	A	B	C	D	E	F

(b) 1st iteration

Time matrix

	A	B	C	D	E	F
A						
B						
C						
D						
E						
F						

Route matrix

	A	B	C	D	E	F
A						
B						
C						
D						
E						
F						

Question 4 continued

(Total for Question 4 is 8 marks)



5.

30

12

5

2

23

18

36

10

15

24



Question 5 continued

(Total for Question 5 is 10 marks)



Question 6 continued

(Total for Question 6 is 10 marks)



SUB-TOPIC 4.1

ACTIVITY NETWORKS AND PRECEDENCE TABLES

Sub-topic 4.1 · 3 questions · 26 marks · lowest tariff first



5.

Activity	Immediately preceding activities
A	—
B	—
C	—
D	A
E	C
F	B, C, D
G	A
H	B, C, D
I	B, C, D, G
J	B, C, D, G
K	E, H

- (a) Draw the activity network described in the precedence table above, using activity on arc. Your activity network must contain only the minimum number of dummies.

(5)

Given that all the activities shown in the precedence table have the same duration,

- (b) state the critical path for the network.

(1)

(Total for Question 5 is 6 marks)



6. The precedence table below shows the twelve activities required to complete a project.

Activity	Immediately preceding activities
A	–
B	–
C	–
D	A
E	A, B
F	D, E
G	A, B, C
H	F, G
I	D, E
J	D, E
K	F, G, I, J
L	I

- (a) Draw the activity network described in the precedence table, using activity on arc. Your activity network must contain the minimum number of dummies only.

(5)



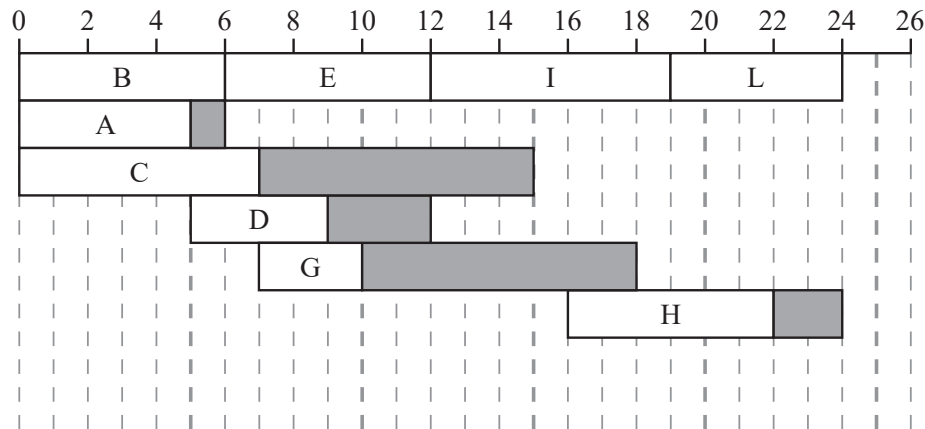


Figure 6

Figure 6 shows a partially completed cascade chart for the project. The non-critical activities F, J and K are **not** shown in Figure 6.

The time taken to complete each activity is given in hours and the project is to be completed in the minimum possible time.

(b) State the critical activities.

(1)

Given that the total float of activity F is 2 hours,

(c) state the duration of activity F.

(1)

The duration of activity J is x hours, and the duration of activity K is y hours, where $x > 0$ and $y > 0$

(d) (i) State, in terms of y , the maximum possible total float for activity K.

(ii) State, in terms of x and y , the total float for activity J.

(2)

(Total for Question 6 is 9 marks)

6. The precedence table below shows the 12 activities required to complete a project.

Activity	Immediately preceding activities
A	—
B	—
C	—
D	A
E	A, B, C
F	A, B, C
G	C
H	D, E
I	D, E
J	D, E
K	F, G, J
L	F, G

(a) Draw the activity network described in the precedence table, using activity on arc.

Your activity network must contain the minimum number of dummies only.

(5)



Each of the activities shown in the precedence table requires one worker. The project is to be completed in the minimum possible time.

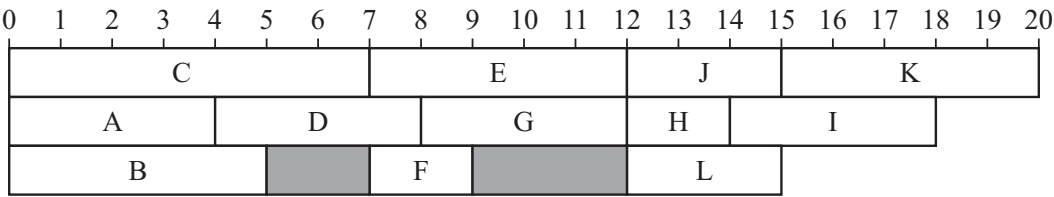


Figure 3

Figure 3 shows a schedule for the project using three workers.

- (b) (i) State the critical path for the network.
- (ii) State the minimum completion time for the project.
- (iii) Calculate the total float on activity B.
- (iv) Calculate the total float on activity G.

(4)

Immediately after the start of the project, it is found that the duration of activity I, as shown in Figure 3, is incorrect. In fact, activity I will take 8 hours. The durations of all the other activities remain as shown in Figure 3.

- (c) Determine whether the project can still be completed in the minimum completion time using only three workers when the duration of activity I is 8 hours. Your answer must make specific reference to workers, times and activities.

(2)

(Total for Question 6 is 11 marks)

SUB-TOPIC 4.3

CRITICAL PATH AND EVENT TIMES

Sub-topic 4.3 · 3 questions · 31 marks · lowest tariff first



2.

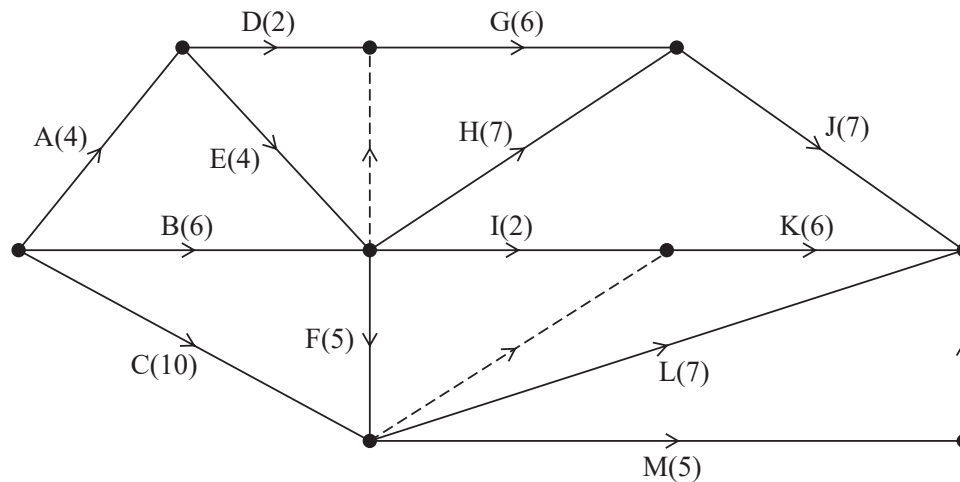


Figure 2

A project is modelled by the activity network shown in Figure 2. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, to complete the corresponding activity.

- (a) Complete Diagram 1 in the answer book to show the early event times and the late event times.

(4)

Each activity requires one worker and the project must be completed in the shortest possible time using as few workers as possible.

- (b) Calculate a lower bound for the number of workers needed to complete the project in the shortest possible time. You must show your working.

(2)

- (c) Schedule the activities using Grid 1 in the answer book.

(3)

(Total for Question 2 is 9 marks)



4.

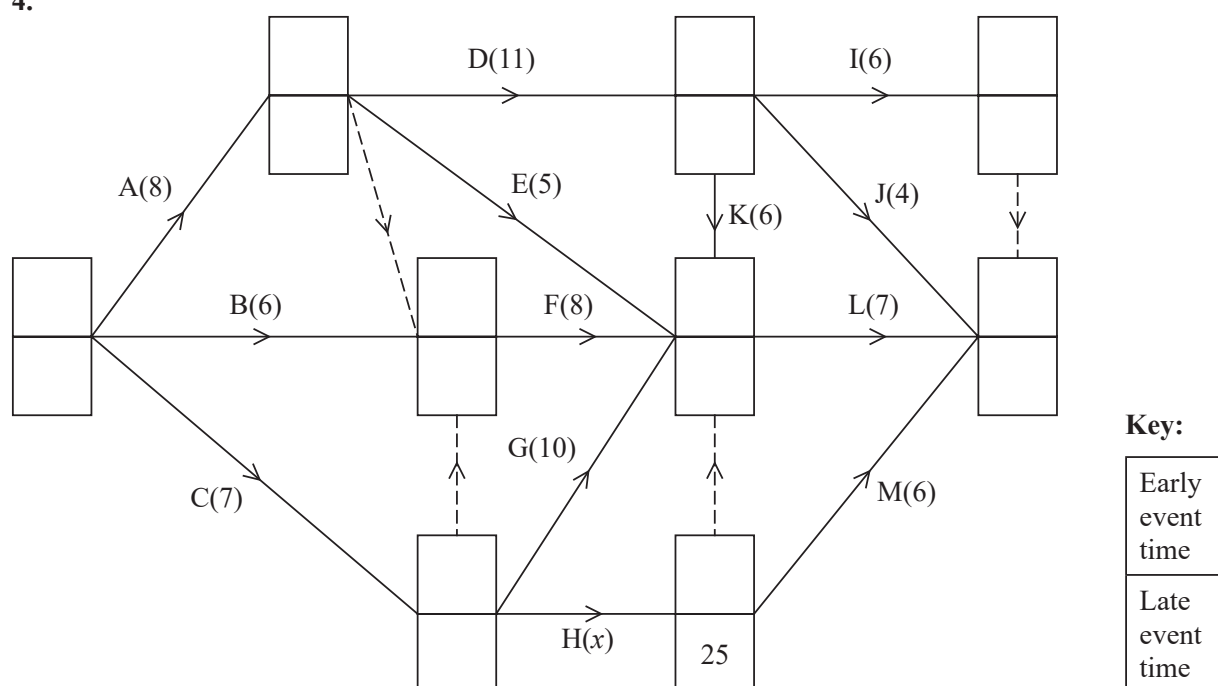


Figure 3

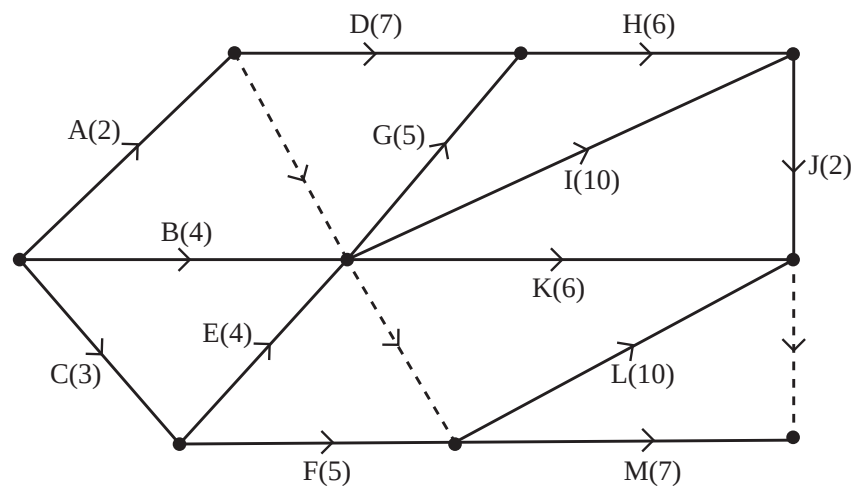
The network in Figure 3 shows the activities that need to be undertaken to complete a project. Each activity is represented by an arc and the duration of the activity, in days, is shown in brackets. The early event times and late event times are to be shown at each vertex and one late event time has been completed for you.

The total float of activity H is 7 days.

- (a) Explain, with detailed reasoning, why $x = 11$ (2)
- (b) Determine the missing early event times and late event times, and hence complete Diagram 1 in your answer book. (3)
- Each activity requires one worker and the project must be completed in the shortest possible time using as few workers as possible.
- (c) Calculate a lower bound for the number of workers needed to complete the project in the shortest possible time. (1)
- (d) Schedule the activities using Grid 1 in the answer book. (3)

(Total for Question 4 is 9 marks)

6.

**Figure 3**

A project is modelled by the activity network shown in Figure 3. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, to complete the corresponding activity. The project is to be completed in the shortest possible time.

- (a) Complete Table 1 in the answer book to show the immediately preceding activities for each activity.

(2)

- (b) Complete Diagram 1 in the answer book to show the early event times and the late event times.

(4)

- (c) Draw a Gantt chart for this project on Grid 1 in the answer book.

(4)

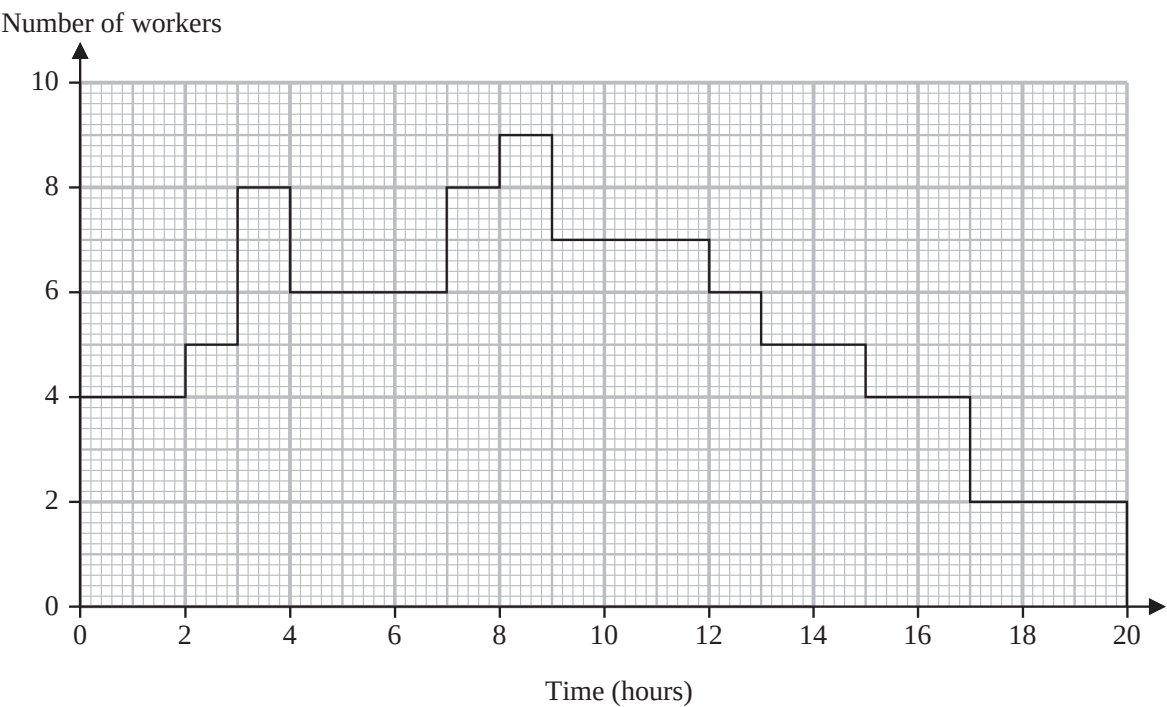


Figure 4

The resource histogram in Figure 4 shows the number of workers required when each activity starts at its earliest possible time. When an activity is started it must be completed without interruption. Each activity requires at least one worker.

(d) By considering which activities are happening each hour, and by working backwards from the minimum project completion time, complete Table 2 in the answer book to show the number of workers needed for each activity.

(3)

(Total for Question 6 is 13 marks)

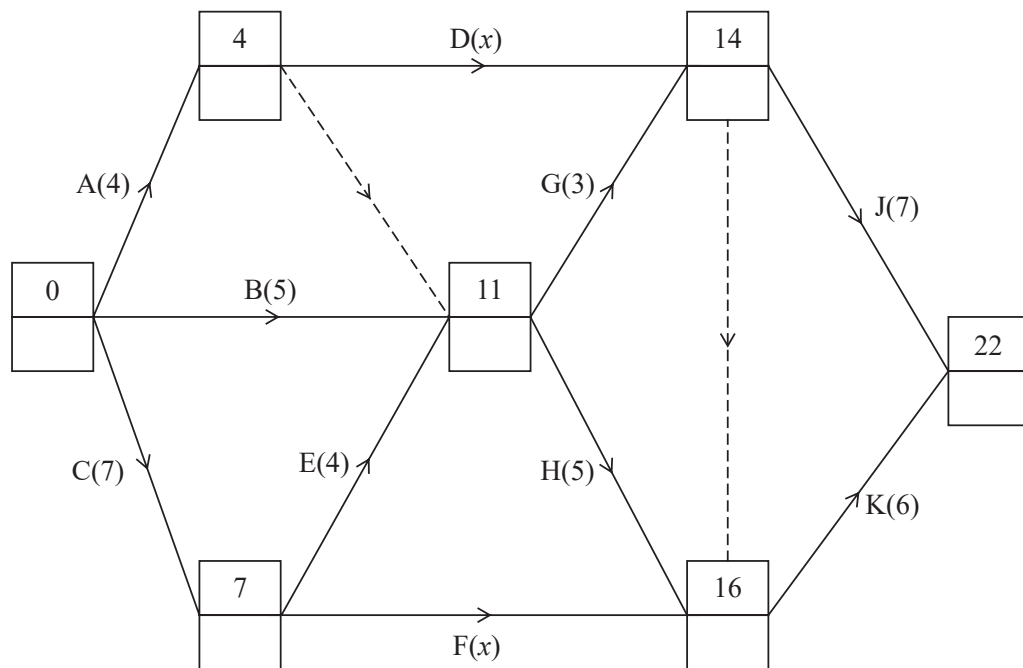
SUB-TOPIC 4.4

FLOAT AND GANTT CHARTS

Sub-topic 4.4 · 1 question · 14 marks · lowest tariff first



5.

**Key:**

Early event time
Late event time

Figure 2

The network in Figure 2 shows the activities that need to be completed for a project. Each activity is represented by an arc and the duration of the activity, in days, is shown in brackets. The early event times are shown in Figure 2.

- (a) Complete Table 1 in the answer book to show the immediately preceding activities for each activity.

(2)

It is given that $4 < x \leq m$

- (b) State the largest possible integer value of m .

(1)

- (c) (i) Complete Diagram 1 in the answer book to show the late event times.

- (ii) State the activities that must be critical.

(3)

- (d) Calculate the total float for activity G.

(1)

The resource histogram in Figure 3 shows the number of workers required when each activity starts at its earliest possible time. The histogram also shows which activities happen at each time.

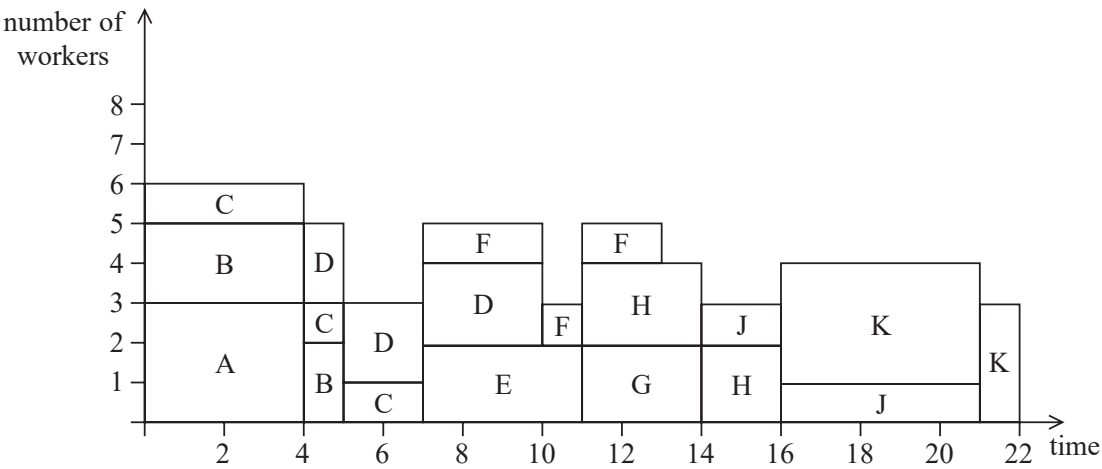


Figure 3

- (e) Complete Table 2 in the answer book to show the number of workers required for each activity of the project. (2)
- (f) Draw a Gantt chart on Grid 1 in the answer book to represent the activity network. (5)

(Total for Question 5 is 14 marks)

MARK SCHEMES

official mark schemes



Question	Scheme	Marks	AOs
6(a)(i)		M1 A1 A1 A1ft	1.1b 1.1b 1.1b 1.1b
	Shortest path from A to H: ABEFGH	A1	2.2a
(a)(ii)	Length of shortest path from A to H is 112	A1ft	2.2a
		(6)	
(b)	Applying Dijkstra repeatedly to n nodes implies that the order is $n(n^2) = n^3$	B1	3.1b
	$t = 0.082 \left(\frac{200}{10} \right)^3$	M1	3.4
	= 656 (seconds)	A1	2.2a
		(3)	
(c)	e.g. order of n^3 does not mean that the order is proportional to n^3 (which is the assumption behind the answer in (b)) but merely means that the dominant term is of order n^3	B1	3.2b
		(1)	
(10 marks)			
Notes: 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 H the working values must be 129 118 112 in that order (so 129 112 118 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			

(a)

M1: A larger value replaced by a smaller value in at least two of the working boxes at either D or F or G or H

A1: All values in A, B, C and E correct. Condone lack of 0 in A's working value

A1: All values D and F correct and the working values in the correct order. Penalise order of labelling only once per question (D and F must be labelled in that order and D must be labelled after A, B, C and E)

A1ft: All values in G and H 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 most likely come from nodes C, D and/or 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 H (which will possibly have working values from C, F and/or G with the order of these values determined by the candidate's order of labelling at C, F and G)

A1: cao - correct path from A to H (ABEFGH)

A1ft: Follow through their final value at H only (if 112 stated and 112 is not the final value at H then **A0**)

(b)

B1: Any indication that repeated application of Dijkstra has cubic order

M1: Complete method – allow 10/200 – allow slips in values e.g. 0.82 for 0.082 and accept 200/10 (or 10/200) either squared or cubed **only**

A1: cao

(c)

B1: Any indication that the run-time is not exactly proportional to n^3 e.g., may suggest that there are other terms ($n^3 + \dots$), or that n^3 is the dominant term, or that order does not imply proportionality. Do not accept only that ' n^3 is not exact'. Condone use of n^2 (oe) for n^3



Qu	Scheme	Marks	AOs
5(a)	e.g. 	M1 A1 A1 A1 A1	1.1b 1.1b 1.1b 1.1b 1.1b
		(5)	
(b)	Critical path: ADHK	B1	2.2a
		(1)	
(6 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. B, C and D 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 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 (a) M1: At least nine activities (labelled on arc), one start, at least two dummies placed A1: Activities A, B, C, D, E, G dealt with correctly A1: Activities F, H and first two dummies + arrows dealt with correctly (the first two dummies are those that are required at the event at the end of activity B) A1: Activities I, J and K dealt with correctly (note that I and J can start directly after the end of G) A1: CSO – Final dummy + arrow, all arrows present for every activity with one finish and no additional dummies. Note that this is not a unique solution e.g. I, J could be interchanged, or the dummy could come after I or J, F and K could lead into the dummy etc. so please check these carefully. Please check all arcs carefully for arrows – if there are no arrows on dummies then M1A1max 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 (b) B1: CAO (ADHK only)			

Question	Scheme	Marks	AOs
6. (a)		M1 A1 A1 A1 A1	2.1 1.1b 1.1b 1.1b 1.1b
		(5)	
(b)	Critical activities: B, E, I and L	B1	2.2a
		(1)	
(c)	(Earliest start for F is 12 and latest finish is 18 therefore if the total float is 2) the duration of F is 4 (hours)	B1	2.2a
		(1)	
(d)	(i) Maximum possible total float for activity K is $5 - y$	B1	3.1b
	(ii) Total float for activity J is $12 - x - y$	B1	2.2a
		(2)	
(9 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. D and E labelled correctly and leading into the same node and F starting from that node but do not consider the end event for F so use the table below for checking as there a number of acceptable answers. Activity on node is M0			

If an arc is not labelled, for example, if the arc for activity C 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 lack of arrows on the activities for the first four marks only (but assume that they are in the ‘correct’ direction for checking purposes)

(a)

M1: At least nine activities (labelled on arc), one start, at least two dummies placed

A1: Activities A, B, C, D, E and the dummy (+ arrow) at the end of A dealt with correctly

A1: Activities G, F, I and J and the dummy (+ arrow) at the beginning of G dealt with correctly

A1: Activities H and L dealt with correctly

A1: CSO – Final two dummies + arrows and activity K dealt with correctly, all arrows present for every activity with one finish and no additional dummies

Please check all arcs carefully for arrows – if there are no arrows on dummies then M1max

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

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

(b)

B1: CAO (B, E, I and L only)

(c)

B1: CAO (4)

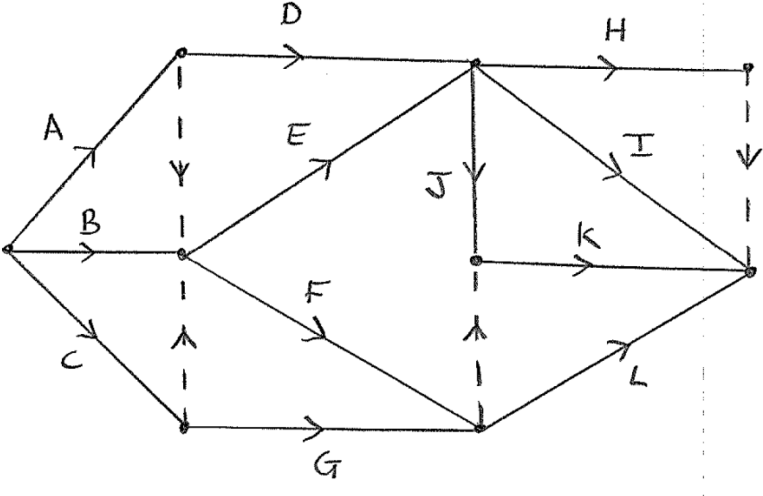
(d)(i)

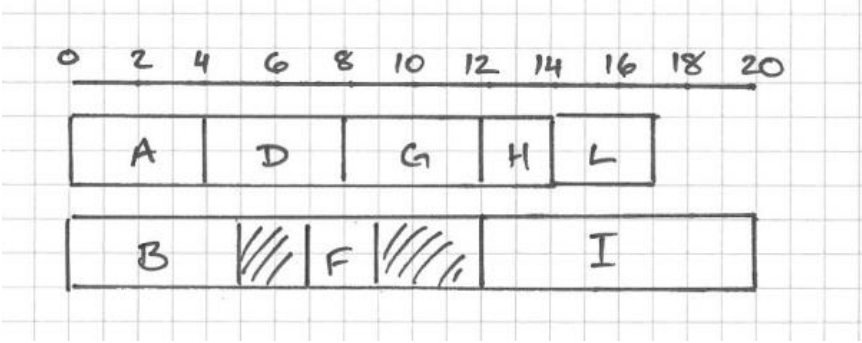
B1: CAO ($5 - y$)

(d)(ii)

B1: CAO ($12 - x - y$)



Question	Scheme	Marks	AOs
6. (a)	e.g. 	M1 A1 A1 A1 A1	2.1 1.1b 1.1b 1.1b 1.1b
		(5)	
(b)(i)	Critical path: C – E – J – K	B1	1.1b
(ii)	Minimum completion time: 20	B1	1.1b
(iii)	Total float on activity B is 2	B1	1.1b
(iv)	Total float on activity G is 4	B1	3.1b
		(4)	
(c)	e.g. (One worker continues to do the critical activities (in time 20)) Second worker completes A, D, G and H as originally planned but now completes activity L in the interval 14 to 20 (but must have started L by time 17 at the latest due to its duration of 3) Third worker completes B and F as planned but now completes activity I exactly in the time interval 12 to 20 so yes, the project can be completed by 3 workers	B2, 1, 0	2.4 2.4

	e.g.  Yes – can be completed by 3 workers		
		(2)	
(11 marks)			

For reference



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. 'H dealt with correctly' requires the correct precedences for this activity, i.e. D and E labelled correctly and leading into the same node and H starting from that node but do not consider the end event for H. **Activity on node is M0**

If an arc is not labelled, for example, if the arc for activity C 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)

Note: if they make multiple attempts which are not clearly replaced mark the one which is best for the candidate

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

(a) M1: At least nine activities (labelled on arc), one start, at least two dummies placed

A1: Activities A, B, C, D and G dealt with correctly

A1: Activities E, F, H, I and J and the first two dummies (+ arrows) at the ends of A and C dealt with correctly (note H and I are interchangeable)

A1: Activities K, L and dummy at the end of F/G (+ arrow) dealt with correctly

A1: CSO – Final dummy (+ arrow) for uniqueness of H/I, all arrows present for every activity with one finish and no additional dummies. (Note direction of arrow on dummy between H and I is interchangeable) (Note the dummy could also be drawn at the start of H and I)

Please check all arcs carefully for arrows – if there are no arrows on dummies then M1A1max

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

(b)(i)

B1: CAO (critical path CEJK – in this order)

(ii)

B1: CAO (20)

(iii)

B1: CAO (2 – total float on B)

(iv)

B1: CAO (4 – total float on G)

(c)

B1: Award this mark with an indication that either

- activities I and L have swapped workers
- activity H has swapped worker and I now starts at 12

B1: dependent on first B mark – **must have a time reference for both I and either L or H for this mark (L or H may be a range)** completely correct reasoning including mention of workers, times and activities (for example, clear indication that (H and) L (in either order) must take place in the interval 12 to 20 **and** that I must now be done in the interval 12 to 20 or states starts at 12 but not just ends at 20) and either concludes **yes or clearly implies that it can be completed on time**

Note their explanation must not include an incorrect statement

Alternatively redraws the schedule for worker 2 and 3 with one completing H and L (in either order) in the time interval 12 – 20 and the other completing I **and** concludes that the project can be completed by 3 workers



Question	Scheme	Marks	AOs
2(a)		M1 A1 M1 A1	2.1 1.1b 1.1b 1.1b
		(4)	
(b)	$\frac{71}{22} = \dots$	M1	1.1b
	$\dots = 3.22\dots$ therefore 4 workers	A1	2.2a
		(2)	
(c)	e.g.	M1 A1 A1	2.1 1.1b 1.1b
		(3)	
(9 marks)			
Notes: (a) M1: All top boxes completed, number generally increasing L to R (condone one “rogue”) A1: cao - top boxes (including zero at the source node) M1: All bottom boxes completed, numbers generally decreasing R to L (condone one “rogue”) A1: cao - bottom boxes (including zero at the sink node)			

(b)

M1: Attempt to find the lower bound $(71 \pm 10) /$ their completion time (a value of 3.2... seen with no working can imply this mark)

A1: cso - correct calculation seen or 3.2 followed by 4. An answer of 4 with no working scores

M0A0

(c)

M1: Not a cascade chart, 4 'workers' used at most and at least 9 different activities placed

A1: 4 workers. All 13 activities present (just once – so if an activity appears for two different workers and is happening at the same time this is A0). 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

A1: 4 workers. All 13 activities present (just once). No errors

Activity	Duration	Time Interval	IPA
A	4	0 – 4	-
B	6	0 – 8	-
C	10	0 – 15	-
D	2	4 – 9	A
E	4	4 – 8	A
F	5	8 – 15	B, E
G	6	8 – 15	B, D, E
H	7	8 – 15	B, E
I	2	8 – 16	B, E
J	7	15 – 22	G, H
K	6	13 – 22	C, F, I
L	7	13 – 22	C, F
M	5	13 – 22	C, F



Qu	Scheme	Marks	AOs
4(a)	The early event time at the end of activity C is 7 (as no other activity leads into this event). Therefore the float on activity H is $25 - 7 - x$	B1	3.1a
	The float on activity H is given as 7 and so therefore $25 - 7 - x = 7$ implies that the value of x is equal to $25 - 7 - 7 = 11$	dB1	2.4
		(2)	
(b)		M1 A1 A1	2.1 1.1b 1.1b
		(3)	
(c)	$\frac{95}{32} = 2.968... = 3$ workers	B1	2.2a
		(1)	
(d)	e.g.	M1 A1 A1	2.1 1.1b 1.1b
		(3)	
(9 marks)			

Notes for Question 4

(a) B1: correct reasoning for why the float on activity H is given by $25 - 7 - x$, must mention that the early event time at the end of activity C is 7 or the early event time at the start of H is 7 **and** that the total float for H is therefore $25 - 7 - x$ (or $25 - x - 7$ but not just $18 - x$) (no reason for why the early event time at the end of C is 7 is required)

dB1: correct explanation for why $x = 11$ (dependent on previous B mark) – as a minimum must equate $25 - 7 - x$ to 7 (allow $18 - x = 7$ as they must have shown where the 18 comes from to get the first B mark) and hence $x = 11$

SC B1B0 – for those who write or imply $25 - 7 - x = 7$ (but not just $18 - x = 7$) and state $x = 11$ without any mention of the early event time at the end of C or the total float of activity H. However, $25 - 7 - 7 = 11$ only is no marks in this part

(b) M1: All top boxes and all bottom boxes completed. Values generally increasing left to right (for top boxes) and values generally decreasing from right to left (for bottom boxes). Condone missing 0s at the source node or the 32 in the bottom box at the sink node for M only. Condone one rogue value in top boxes and one rogue value in bottom boxes. For a rogue in the top boxes 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 (with a similar definition for bottom boxes but in reverse)

A1: CAO - Top boxes (including zero at the source node)

A1: CAO - Bottom boxes (including zero at the sink node)

(c) B1: Correct calculation seen then 3 – an answer of 3 with no working scores B0

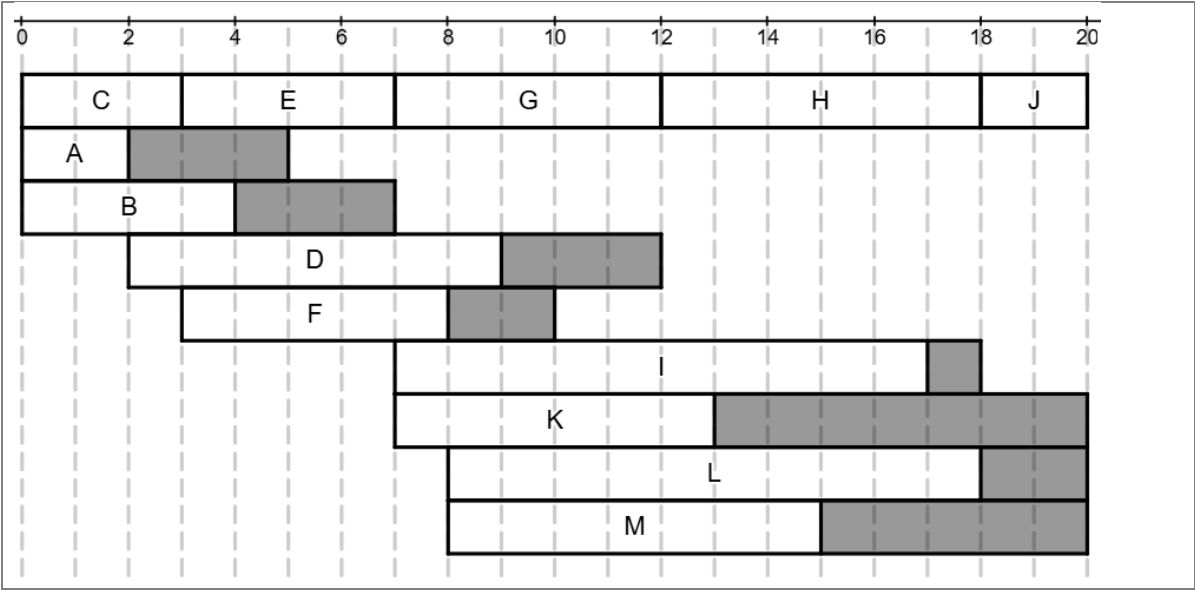
(d) M1: Not a cascade chart. 4 ‘workers’ used at most and at least 10 different activities placed

A1: 4 workers. All 13 activities present (just once – so if an activity appears for two different workers and is happening at the same time this is A0). 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

A1: 4 workers. All 13 activities present (just once). No errors

Activity	Duration	Time interval	IPA
A	8	0 - 8	-
B	6	0 - 17	-
C	7	0 - 14	-
D	11	8 - 19	A
E	5	8 - 25	A
F	8	8 - 25	A, B, C
G	10	7 - 25	C
H	11	7 - 25	C
I	6	19 - 32	D
J	4	19 - 32	D
K	6	19 - 25	D
L	7	25 - 32	E, F, G, H, K
M	6	18 - 32	H





Question	Scheme	Marks	AOs
5(a)	B -	B1	1.1b
	C -		
	D A		
	E C		
	G A, B, E		
	H A, B, E		
	J D, G		
	K D, F, G, H		
		(2)	
(b)	$(m =) 9$	B1	2.2a
		(1)	
(c)	(i) (ii) C, E, H and K must be critical	M1	1.1b
		A1	1.1b
		B1	2.2a
		(3)	
(d)	Total float for activity G is $15 - 11 - 3 = 1$	B1	2.2a
		(1)	

(e)	<table><tr><th>Activity</th><th>Workers</th></tr><tr><td>A</td><td>3</td></tr><tr><td>B</td><td>2</td></tr><tr><td>C</td><td>1</td></tr><tr><td>D</td><td>2</td></tr><tr><td>E</td><td>2</td></tr></table>	Activity	Workers	A	3	B	2	C	1	D	2	E	2	<table><tr><th>Activity</th><th>Workers</th></tr><tr><td>F</td><td>1</td></tr><tr><td>G</td><td>2</td></tr><tr><td>H</td><td>2</td></tr><tr><td>J</td><td>1</td></tr><tr><td>K</td><td>3</td></tr></table>	Activity	Workers	F	1	G	2	H	2	J	1	K	3	B1	1.1b
	Activity	Workers																										
	A	3																										
	B	2																										
	C	1																										
	D	2																										
	E	2																										
Activity	Workers																											
F	1																											
G	2																											
H	2																											
J	1																											
K	3																											
B1	1.1b																											
		(2)																										
(f)	$x = 6$ 0 2 4 6 8 10 12 14 16 18 20 22 C E H K A B D F G J	B1	3.1b																									
	M1	2.1																										
	A1	1.1b																										
	A1	1.1b																										
	A1	1.1b																										
			(5)																									
(14 marks)																												



Notes for Question 5

a1B1: Four correct rows (not including the rows for A, B and C)

a2B1: All rows correct (accept blanks or dashes (etc.) for A, B and C but any letters placed in these three rows scores B0)

b1B1: cao for the value of m – allow $4 < x$, 9 or x , 9 but not $x = 9$ or m , 9 unless stating the correct value too

ci1M1: Any four of the bottom boxes completed correctly

ci1A1: cao – all bottom boxes completed correctly. The $15 - x$ **must** be seen to award this mark (but may be crossed out). Condone this correct expression being replaced with their value of $15 - x$ ONLY if their value of x is **explicitly** stated either here or later in their solution

cii1B1: cao (C, E, H and K only)

d1B1: cao – a correct answer with no working (or no incorrect working) can imply this mark

e1B1: Any six values correct

e2B1: cao

f1B1: cao for the value of x (seen or implied, e.g., duration of D **and** F both correct so therefore must be consistent)

f1M1: Cascade chart with at least 8 activities labelled and at least four activities having non-zero float. A scheduling diagram (so a diagram in which no floats are evident) scores M0

f1A1: Critical activities (C, E, H and K) correct

f2A1: Activities B, G and J correct

f3A1: Activities A, D and F correct

For (f) the following may be useful in checking their cascade chart provided the float is shown after the corresponding activity:

Activity	Duration + Float
A	0 to 4 F: 4 to 9
B	0 to 5 F: 5 to 11
C	0 to 7 Critical
D	4 to 10 F: 10 to 15

Activity	Duration + Float
E	7 to 11 Critical
F	7 to 13 F: 13 to 16
G	11 to 14 F: 14 to 15
H	11 to 16 Critical

Activity	Duration + Float
J	14 to 21 F: 21 to 22
K	16 to 22 Critical



Qu	Scheme	Marks	AOs												
	<table><tr><td>n</td><td>a</td><td>b</td><td>c</td></tr><tr><td>5</td><td>1</td><td>3</td><td>3</td></tr><tr><td></td><td>2</td><td>2</td><td>8</td></tr></table>	n	a	b	c	5	1	3	3		2	2	8	M1	1.1b
n	a	b	c												
5	1	3	3												
	2	2	8												

