Fd1Ch8 XMQs and MS

(Total: 134 marks)

1. FD1_Sample Q6 . 12 marks - FD1ch8 Critical path analysis
2. FD1_Specimen Q4 . 10 marks - FD1ch8 Critical path analysis
3. FD1_2019 Q4 . 9 marks - FD1ch8 Critical path analysis
4. FD1_2019 Q5 . 6 marks - FD1ch8 Critical path analysis
5. FD1_2020 Q2 . 15 marks - FD1ch8 Critical path analysis
6. FD1_2021 Q2 . 9 marks - FD1ch8 Critical path analysis
7. FD1_2021 Q7 . 8 marks - FD1ch8 Critical path analysis
8. FD1_2022 Q5 . 14 marks - FD1ch8 Critical path analysis
9. FD1(AS)_2018 Q3 . 10 marks - FD1ch8 Critical path analysis
10. FD1(AS)_2019 Q3 . 7 marks - FD1ch8 Critical path analysis
11. FD1(AS)_2020 Q2 . 14 marks - FD1ch8 Critical path analysis
12. FD1(AS)_2021 Q2 . 12 marks - FD1ch8 Critical path analysis
13. FD1(AS)_2022 Q2 . 8 marks - FD1ch8 Critical path analysis

6.

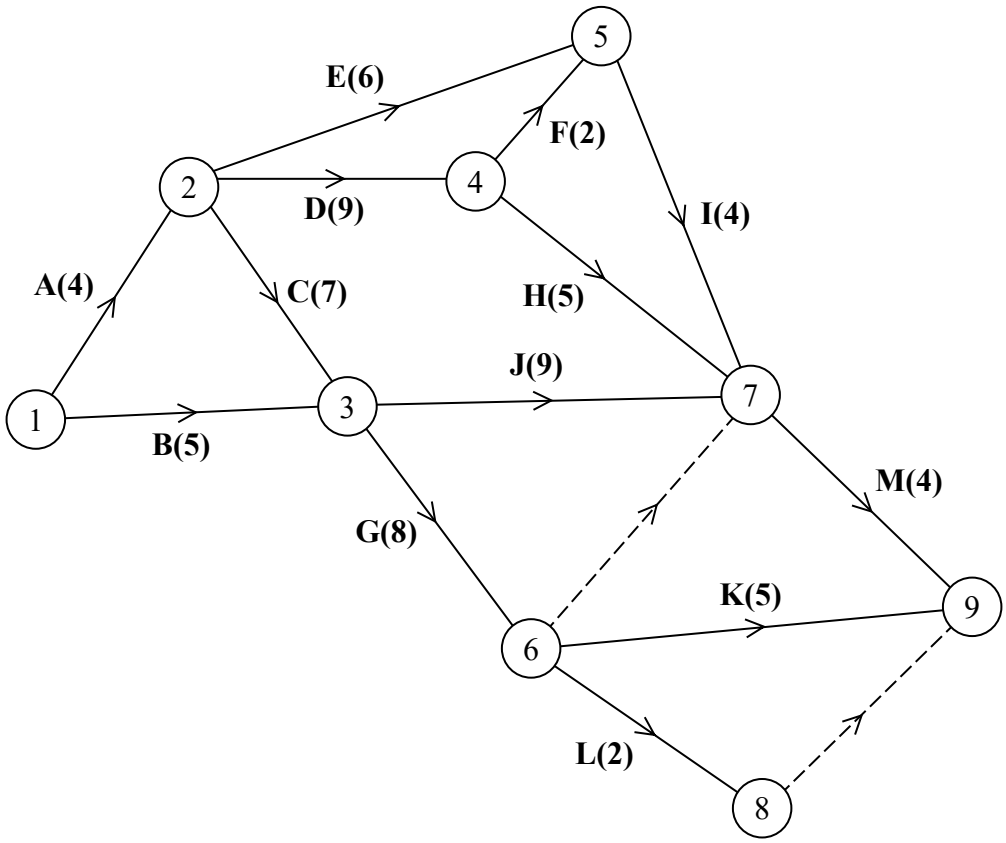


Figure 4

A project is modelled by the activity network shown in Figure 4. The activities are represented by the arcs. The number in brackets on each arc gives the time, in days, to complete that activity. Each activity requires one worker. The project is to be completed in the shortest possible time.

(a) Calculate the early time and the late time for each event, using Diagram 1 in the answer book.

(3)

(b) On Grid 1 in the answer book, complete the cascade (Gantt) chart for this project.

(3)

(c) On Grid 2 in the answer book, draw a resource histogram to show the number of workers required each day when each activity begins at its earliest time.

(3)

The supervisor of the project states that only three workers are required to complete the project in the minimum time.

(d) Use Grid 2 to determine if the project can be completed in the minimum time by only three workers. Give reasons for your answer.

(3)

(Total for Question 6 is 12 marks)

6.

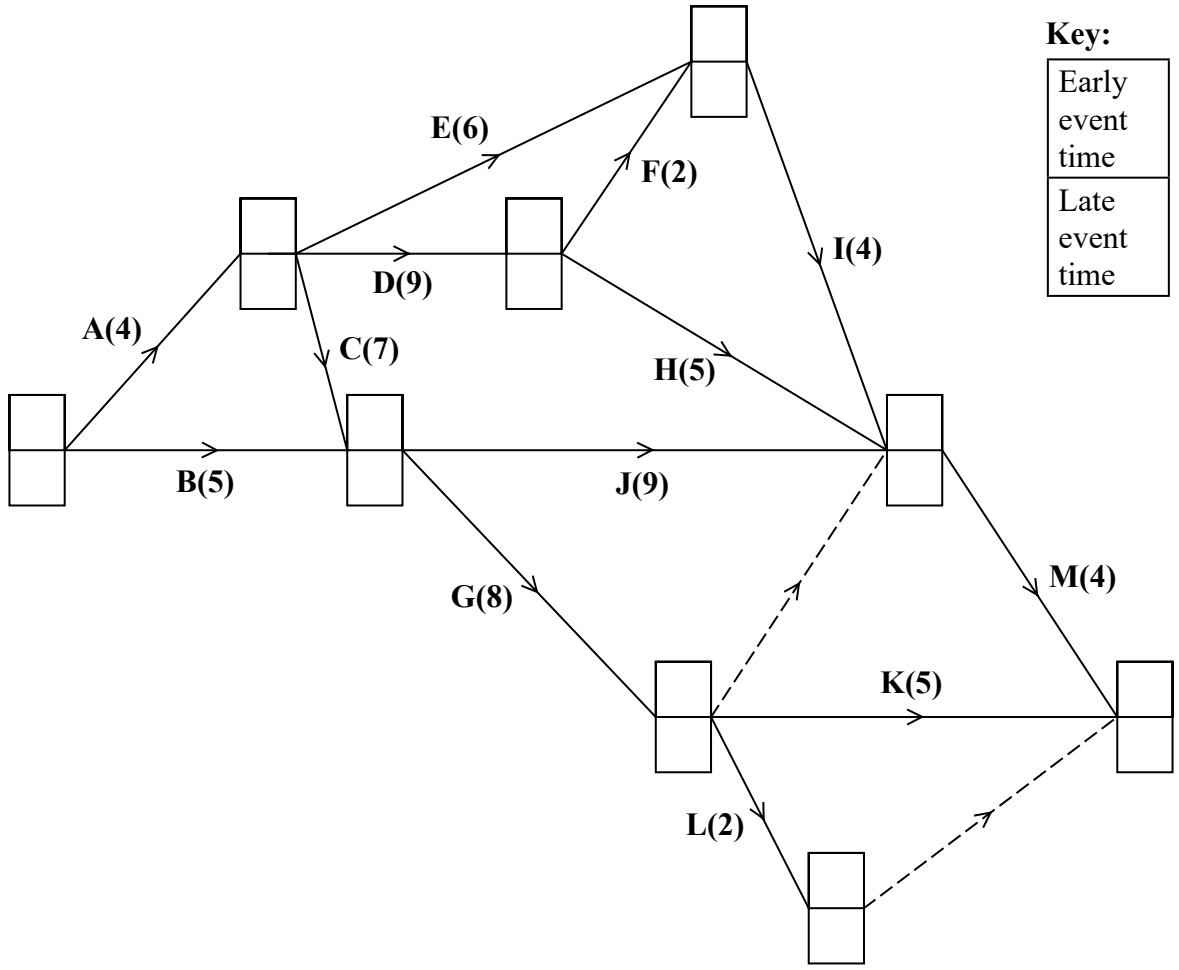
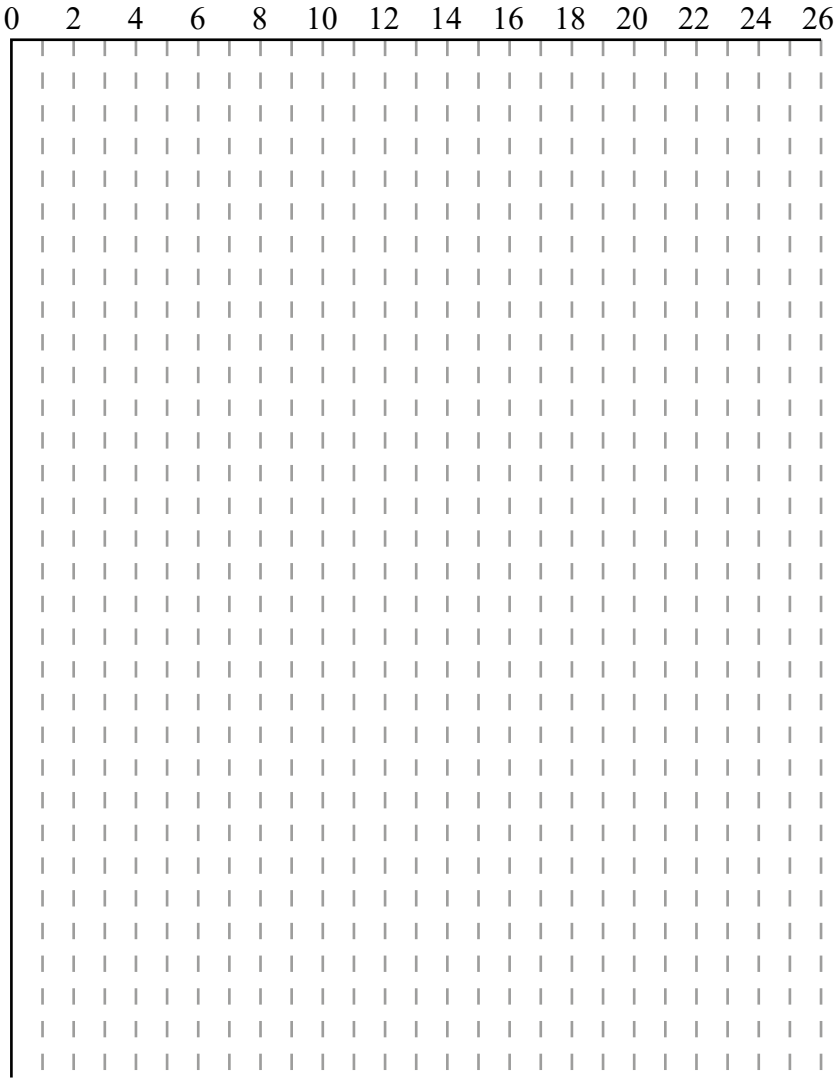


Diagram 1

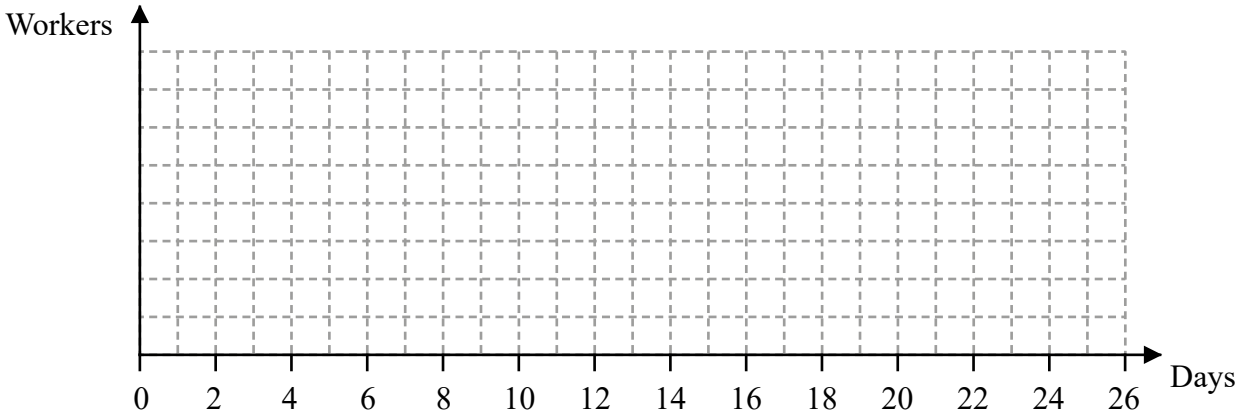
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question 6 continued



Grid 1

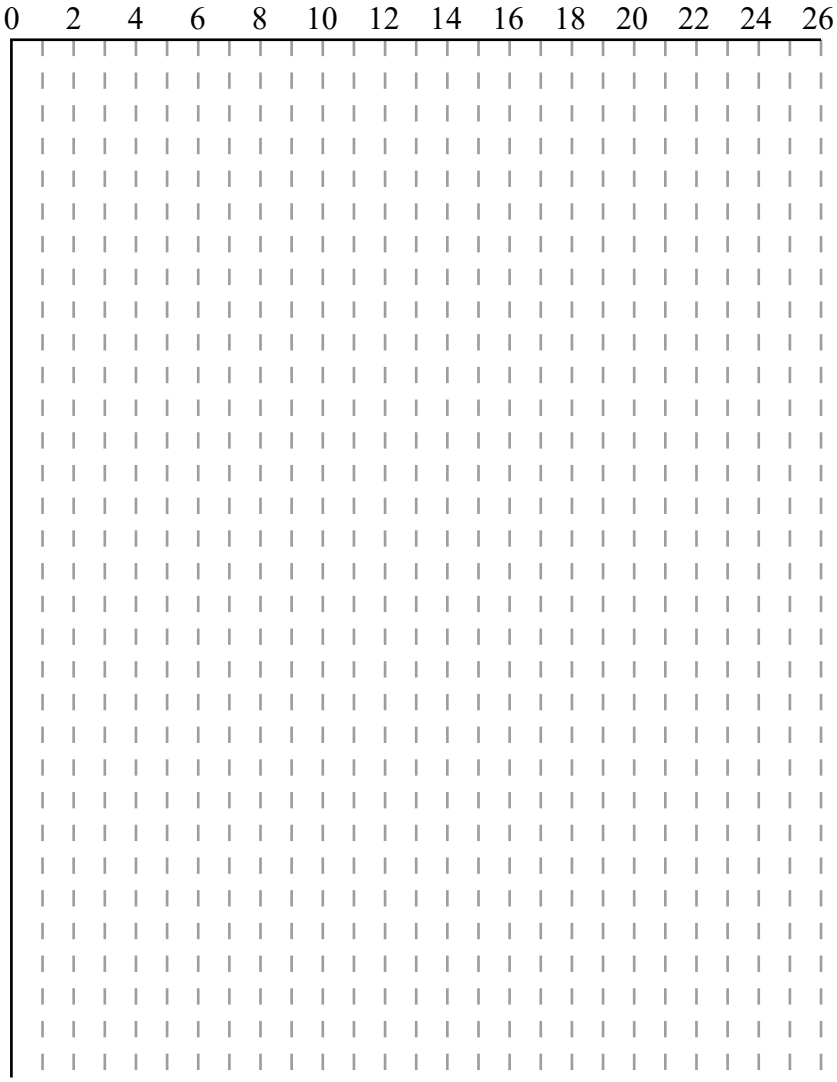
(There is a spare grid on the next page)



Grid 2

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question 6 continued



Copy of Grid 1

(Total for Question 6 is 12 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

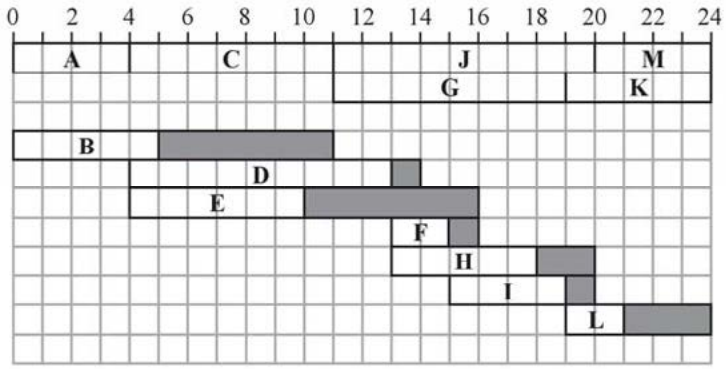
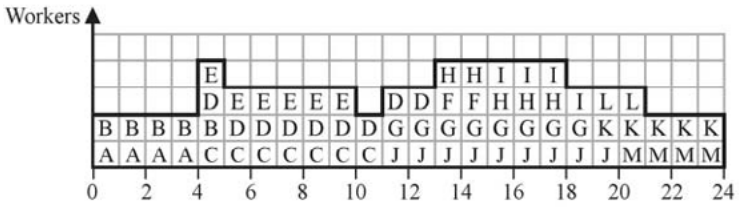
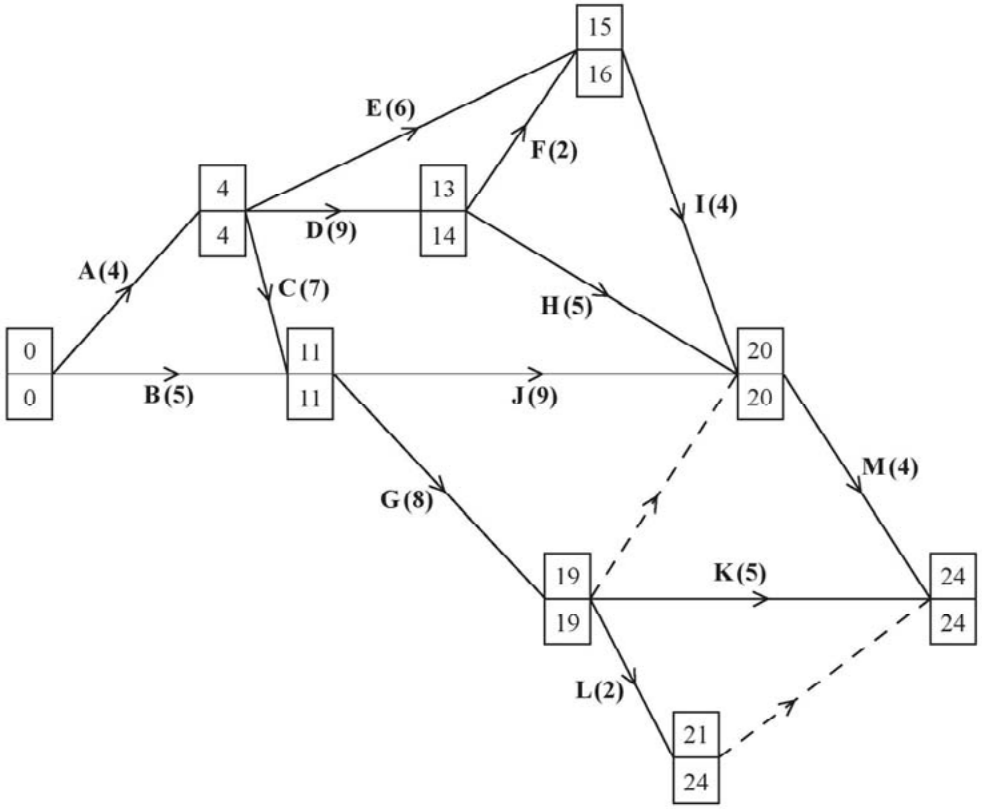
Question	Scheme	Marks	AOs
6(a)	**See diagram on next page.** Top and bottom boxes Top boxes correct	M1 A1	2.1 1.1b
	Bottom boxes correct	A1	1.1b
		(3)	
(b)	See diagram below  		
	At least 8 activities + 4 floats with clear distinction between activity and their corresponding float	M1	2.5
	Correct critical activities + 4 correct non-critical activities	A1	1.1b
	All 13 correct	A1	1.1b
		(3)	
(c)	 	M1	1.1b
	Bars correct to time = 13	A1	1.1b
	Bars correct from 14 to 24	A1	1.1b
		(3)	
(d)	Until time 4 only A and B can happen. After time 4, there are 6 worker-days to cover, but only 4 worker-days available. Hence the project cannot be completed by time 24 with three workers.	B1 M1 A1	3.1a 2.4 2.2a
		(3)	
			(12 marks)

Diagram for Question 6(a)



Question 6 notes:	
(a)	
M1:	All top boxes and all bottom boxes completed. For the top boxes all values must be increasing in the direction of the arrows for both the activities and the dummies. For the bottom boxes all values must be decreasing in the opposite direction to the arrows for both the activities and the dummies. While the values need not be correct each value must be increasing or decreasing (as appropriate) in a logical and sequential manner.
A1:	cao for top boxes
A1:	cao for bottom boxes
M1:	At least 8 activities including 4 floats. Scheduling diagram scores M0 – clear distinction must be shown between the notation used for an activity and its float
(b)	
A1:	Correct critical activities and 4 correct non-critical activities
A1:	cao (all 13 correct activities)
(c)	
M1:	Plausible histogram with no holes or overhangs (must go to at least 10 on the time axis)
A1:	Histogram correct to time 13
A1:	Histogram correct from time 14 to time 24
(d)	
B1:	Considering an appropriate process to adjust Grid 2 so that no activity must be completed by a 4^{th} worker, for example, a correct argument that until time 4 only activities A and B can happen (so no activity can use the spare worker before time 4)
M1:	Uses their histogram to explain when the number of workers is greater or less than the minimum number found in (b)
A1:	Correctly deduces that the project cannot be completed by time 24 – this mark is dependent on a correct histogram seen in (d)

4. The table below lists the durations (in minutes), the immediate preceding activities and the number of workers required for each activity in a project.

Activity	Duration (minutes)	Immediate preceding activities	Number of workers
A	20	-	1
B	15	-	1
C	35	-	2
D	10	C	1
E	35	A	1
F	20	A	2
G	10	A, B, D	1
H	25	C	1
I	30	E	1
J	20	E, F, G, H	2

The project is modelled by the activity network shown in Figure 3. The activities are represented by the arcs. The project is to be completed in the shortest possible time.

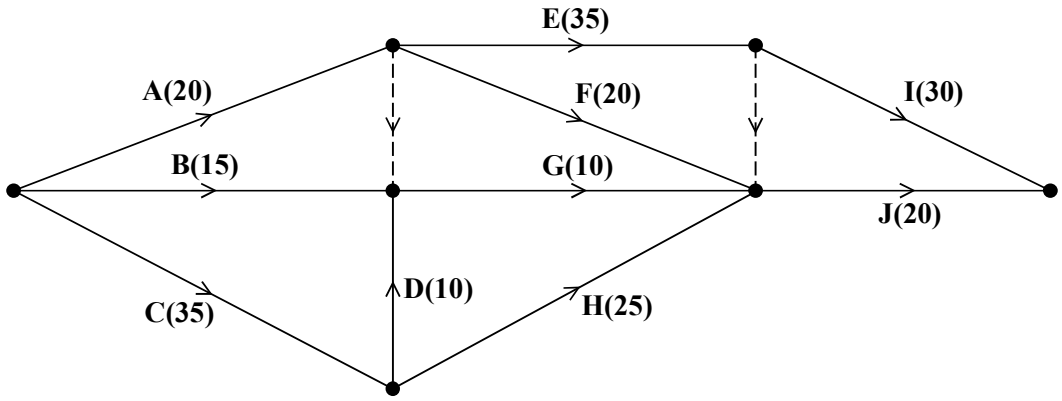


Figure 3

(a) (i) Calculate the early time and the late time for each event, using Diagram 1 in the answer book.

(ii) Determine the minimum project completion time.

(iii) Identify the critical activities.

(5)

(b) On Grid 1 in the answer book, draw a resource histogram to show the number of workers required at each time when each activity begins at its earliest possible start time.

(3)

(c) Determine whether or not the project can be completed in the minimum possible time by at most four workers. You must justify your answer with reference to your resource histogram.

(2)

(Total for Question 4 is 10 marks)

4.

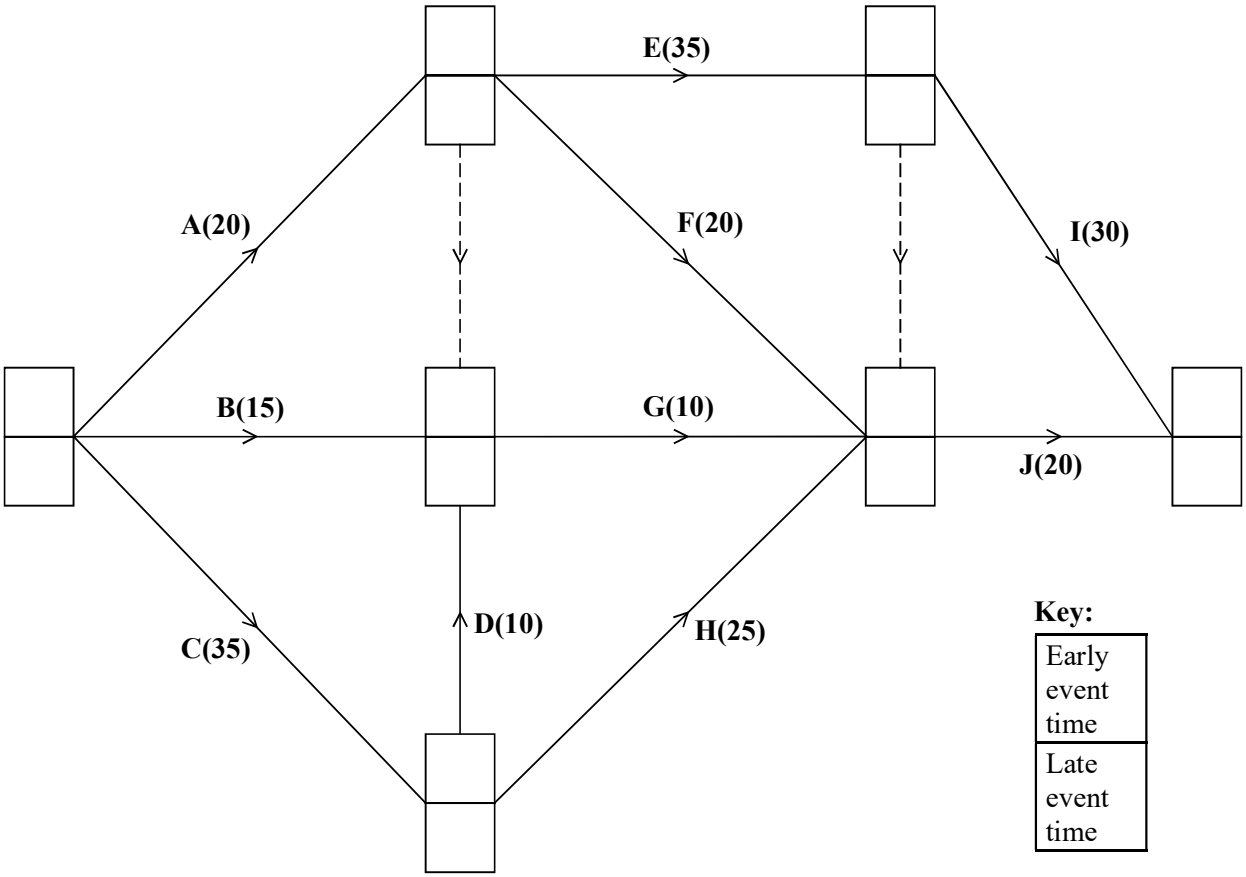
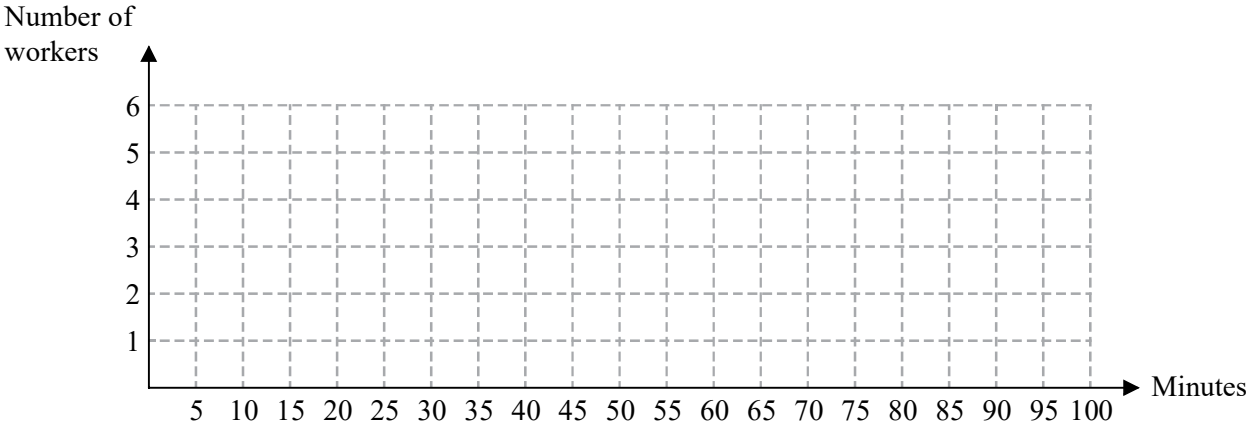


Diagram 1

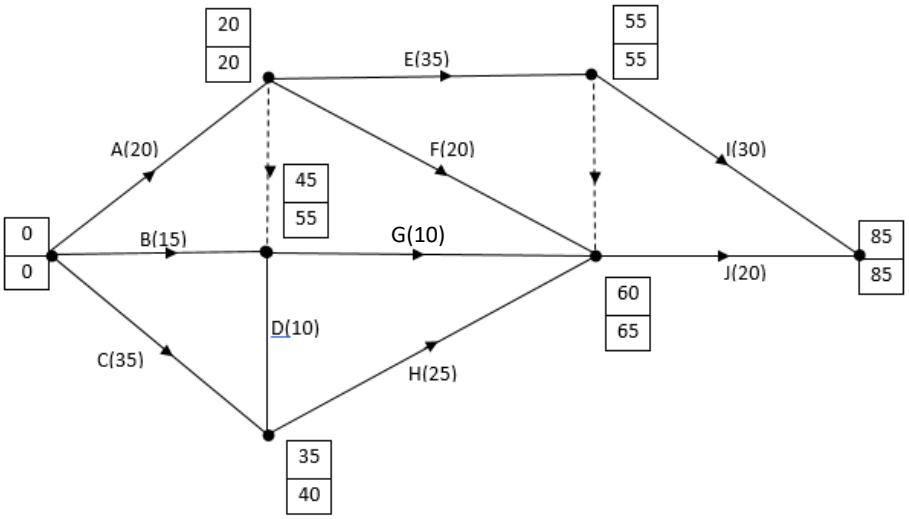
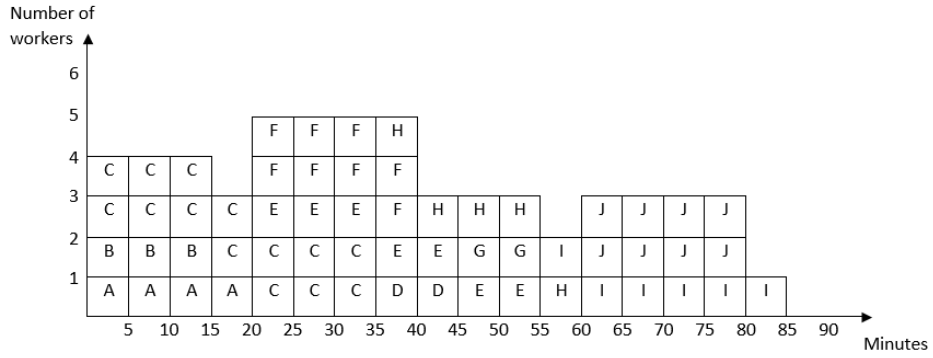
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question 4 continued



(Total for Question 4 is 10 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question	Scheme	Marks	AOs
4(a) **(i)**		M1 A1 A1	2.1 1.1b 1.1b
(ii)	Minimum completion time is 85 minutes	A1ft	2.2a
(iii)	Critical activities are A, E and I	A1ft	2.2a
		(5)	
(b)	e.g. 	M1 A1 A1	1.1b 1.1b 1.1b
		(3)	
(c)	Currently five workers are required between time 20 and 40 and so activities F and H would have to be delayed If F starts at 35 H could not begin until 55 but the latest start time for H is 40. Therefore the project cannot be completed in the minimum time with only four workers	M1 A1	2.4 2.2a
		(2)	
			(10 marks)

Notes:

(a)(i)

M1: All boxes completed, number generally increasing L to R (condone one "rogue") and decreasing R to L (condone one "rogue")

A1: Cao - Top boxes

A1: Cao - Bottom boxes

(ii)

A1ft: Deduction that result in diagram indicates that project can be completed in 85 minutes

(iii)

A1ft: Deduction of correct critical activities (from their values at each event)

(b)

M1: Plausible histogram with no holes or overhangs (must go to at least 70 on the time axis)

A1: Histogram correct to time 40

A1: Histogram correct from time 40 to time 85

(c)

M1: Explanation involving the need to delay activities F and H

A1: Correct deduction that it is not possible to complete the project with only four workers in the minimum project completion time

4.

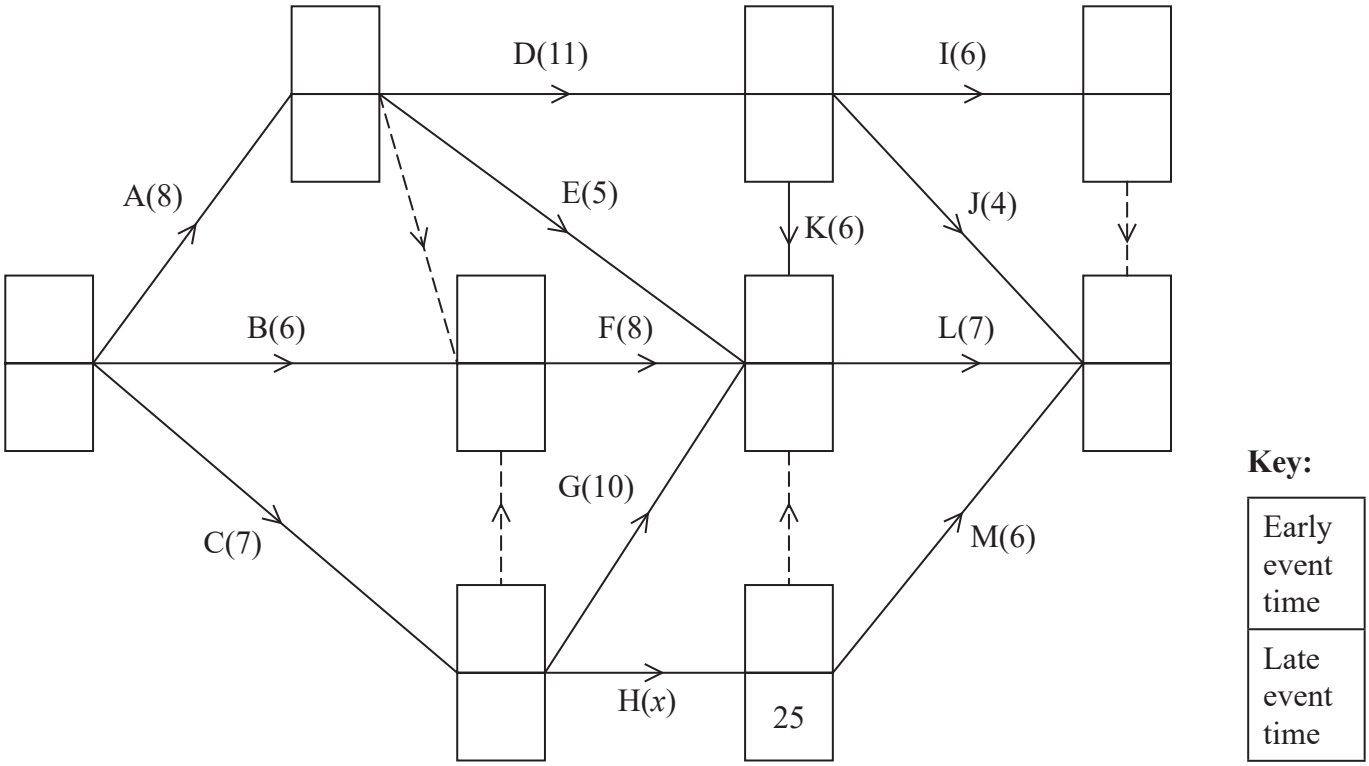


Figure 3

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.

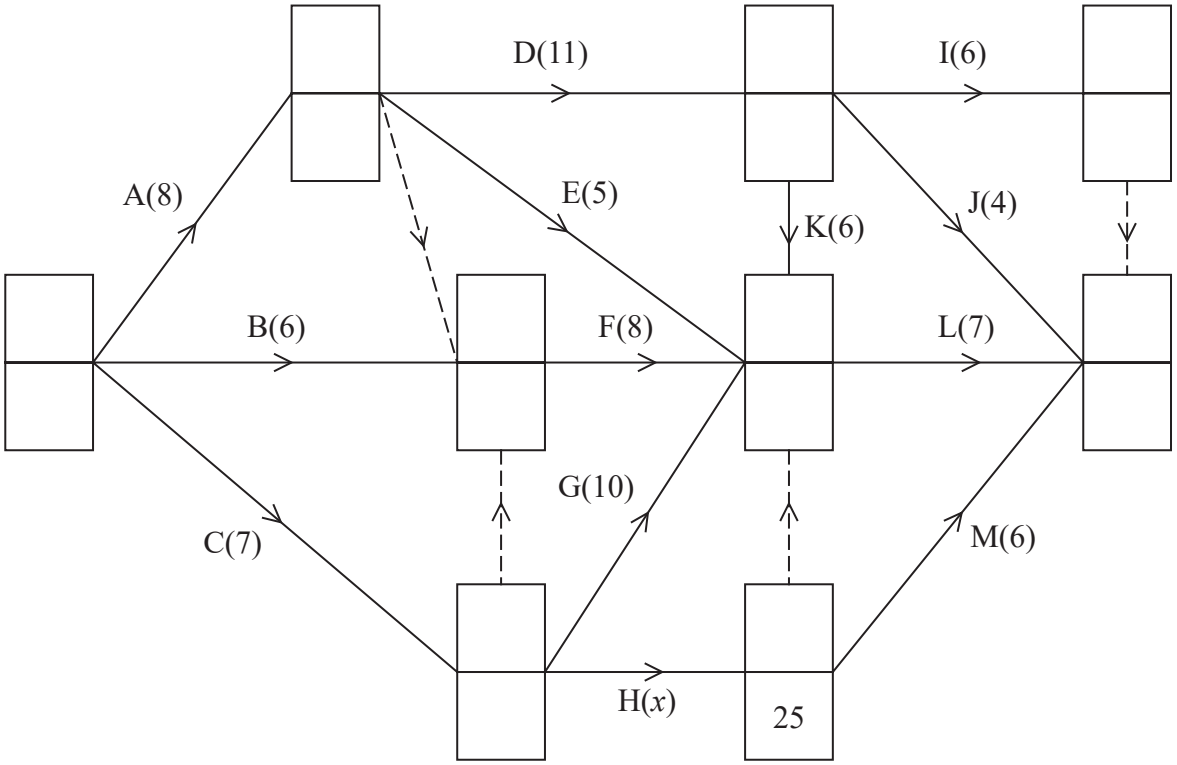
(1)

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

(3)

(Total for Question 4 is 9 marks)

4.



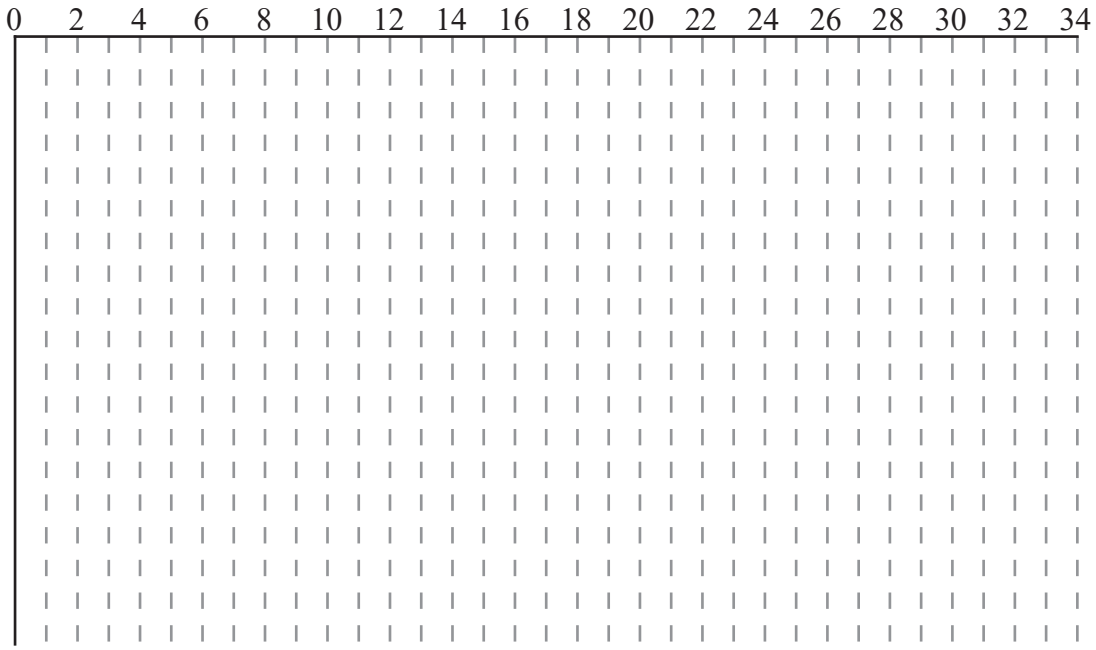
Key:

Early event time
Late event time

Diagram 1

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

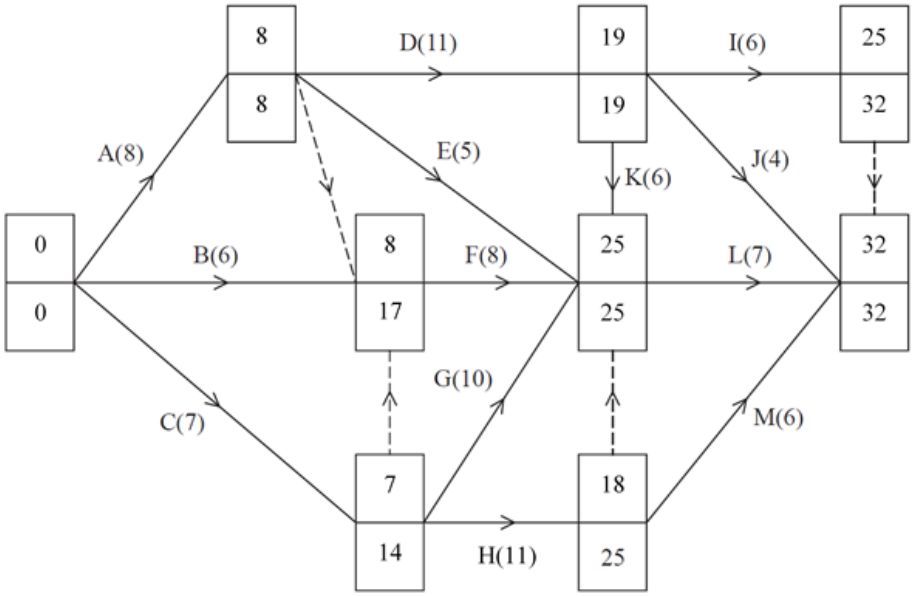
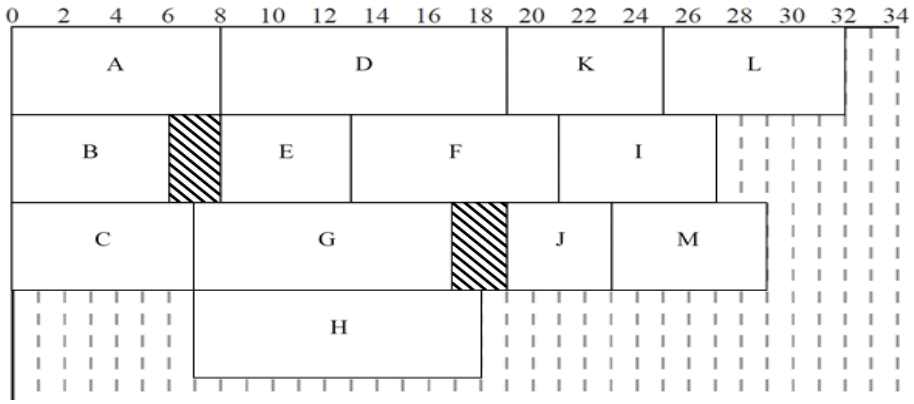
Question 4 continued



Grid 1

(Total for Question 4 is 9 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

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 $25 - 7 - x$ 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 $25 - 7 - 7 = 11$	B1 dB1	3.1a 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

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.

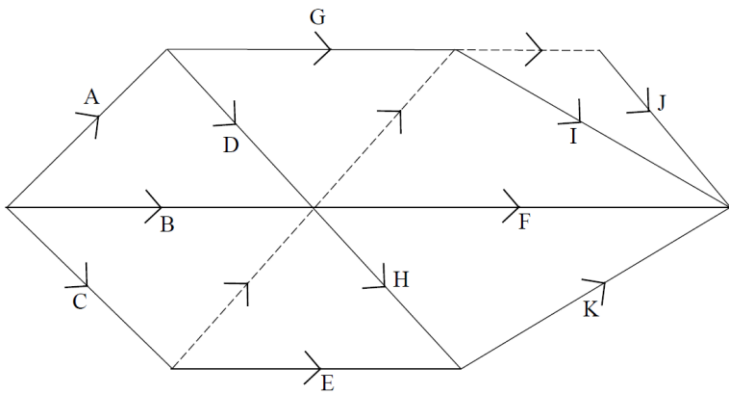
(5)

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)

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)

2.

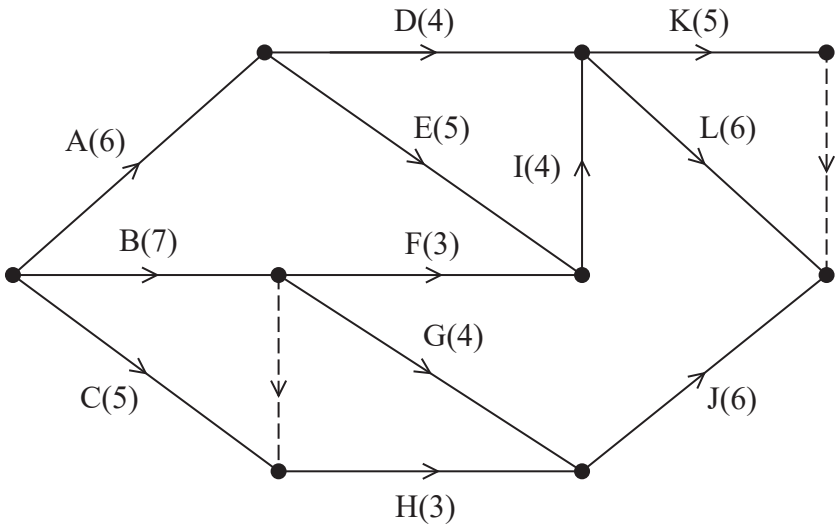


Figure 1

The network in Figure 1 shows the activities that need to be undertaken to complete a project. Each activity is represented by an arc and the duration, in hours, of the corresponding activity is shown in brackets.

(a) Explain why each of the dummy activities is required.

(2)

(b) Complete the table in the answer book to show the immediately preceding activities for each activity.

(2)

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

(ii) State the minimum completion time for the project.

(iii) State the critical activities.

(6)

Each activity requires one worker. Each worker is able to do any of the activities. Once an activity is started it must be completed without interruption.

(d) On Grid 1 in the answer book, draw a resource histogram to show the number of workers required at each time when each activity begins at its earliest possible start time.

(3)

(e) Determine whether or not the project can be completed in the minimum possible time using fewer workers than the number indicated by the resource histogram in (d). You must justify your answer with reference to the resource histogram and the completed Diagram 1.

(2)

(Total for Question 2 is 15 marks)

2. (a)

(b)

Activity	Immediately preceding activities
A	
B	
C	
D	

Activity	Immediately preceding activities
E	
F	
G	
H	

Activity	Immediately preceding activities
I	
J	
K	
L	

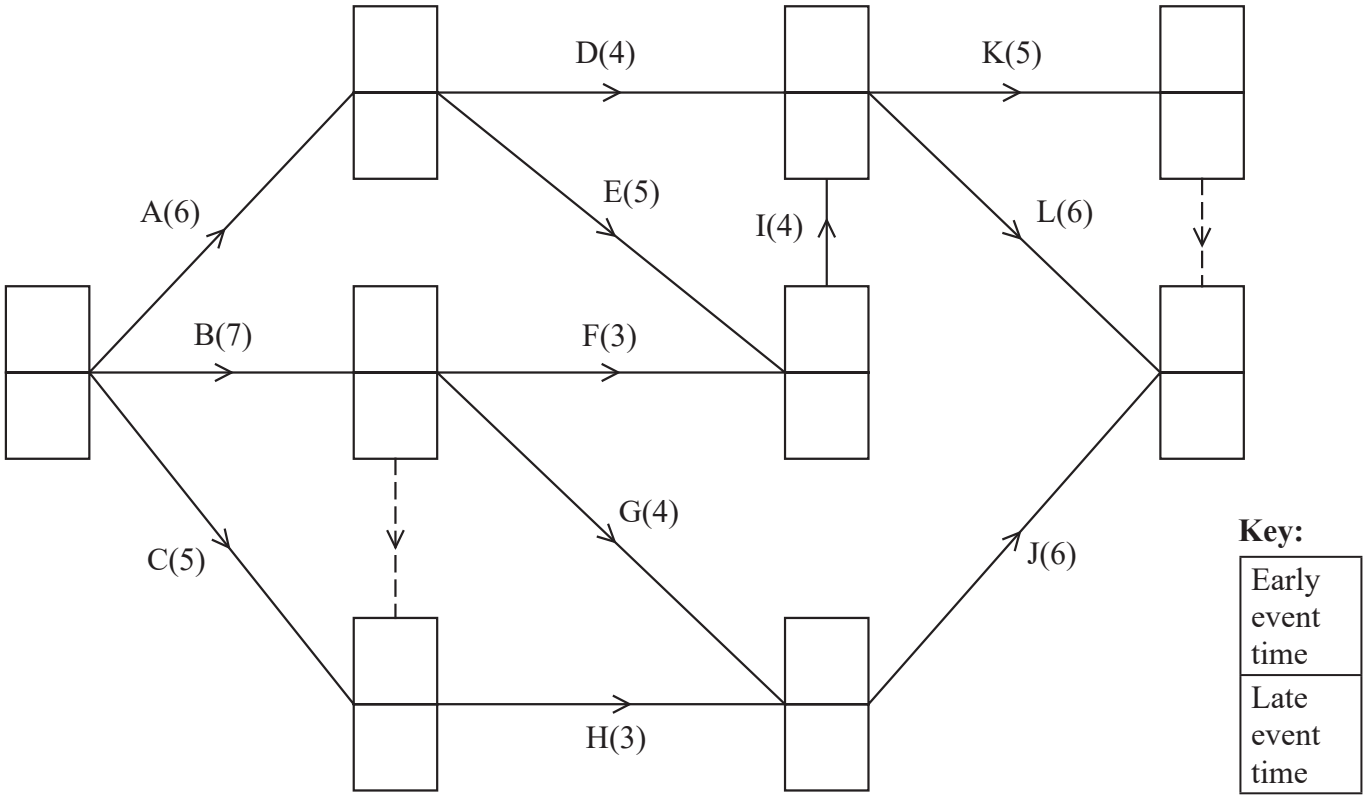
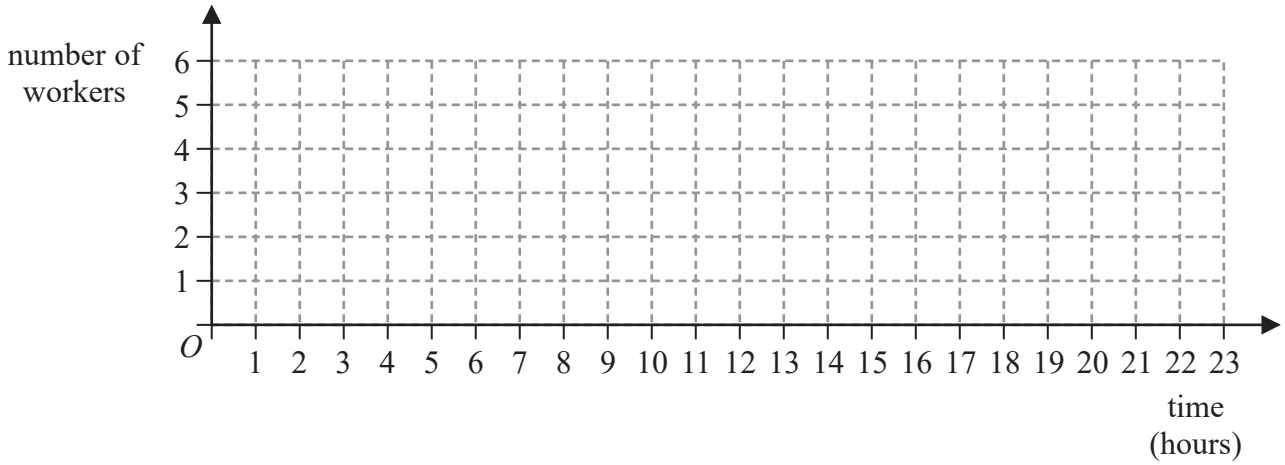


Diagram 1

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

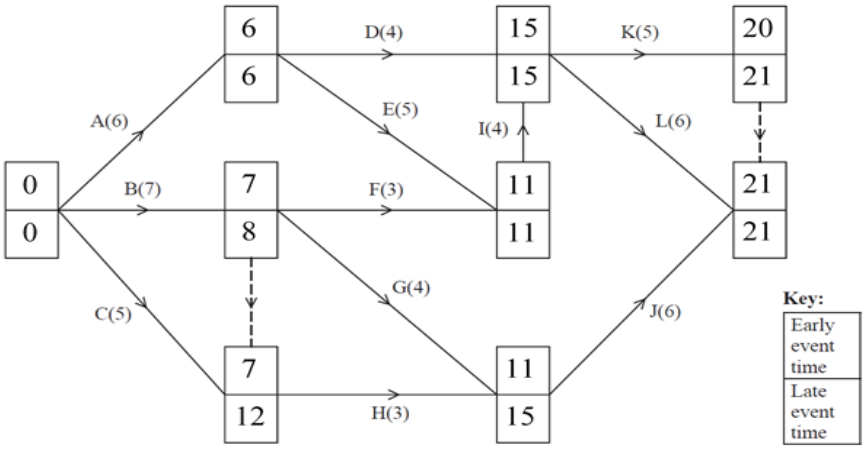
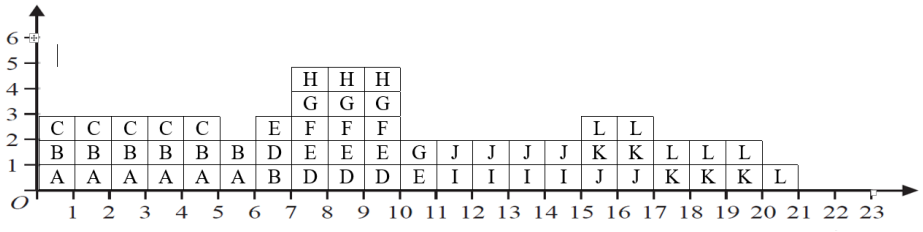
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question 2 continued



Grid 1

(Total for Question 2 is 15 marks)

Question	Scheme	Marks	AOs
2(a)	The dummy at the end of activity B is required as F (and G) are dependent on activity B only, but activity H is dependent on both activities B and C The dummy at the end of activity K is required as two activities cannot start at the same event and finish at the same event	B1 B1	2.4 2.4
		(2)	
(b)	<table><tr><td>Activity</td><td>**IPA**</td><td>Activity</td><td>**IPA**</td><td>Activity</td><td>**IPA**</td></tr><tr><td>A</td><td>**-**</td><td>E</td><td>**A**</td><td>I</td><td>**E, F**</td></tr><tr><td>B</td><td>**-**</td><td>F</td><td>**B**</td><td>J</td><td>**G, H**</td></tr><tr><td>C</td><td>**-**</td><td>G</td><td>**B**</td><td>K</td><td>**D, I**</td></tr><tr><td>D</td><td>**A**</td><td>H</td><td>**B, C**</td><td>L</td><td>**D, I**</td></tr></table>	B1 B1	1.1b 1.1b
		(2)	
(c)(i)		M1 A1 M1 A1	1.1b 1.1b 1.1b 1.1b
(c)(ii)	Minimum completion time: 21 hours	A1ft	1.1b
(c)(iii)	Critical activities: A, E, I, L	A1	1.1b
		(6)	
(d)	e.g. 	M1 A1 A1	1.1b 1.1b 1.1b
		(3)	

(e)	Currently five workers are required between time 7 and 10 and so one of the non-critical activities D, F, G or H would have to be delayed and start after time 10 e.g. Activity H could be delayed and start at time 10 (as it has sufficient total float and can finish as late as time 15) and so the project can be completed with fewer workers than the number indicated by the resource histogram as J could be delayed too and start at time 15	M1 A1	2.4 2.2a
		(2)	
			(15 marks)

Notes for Question 2

(a)

B1: Correct explanation for precedence dummy (must mention B, C, H and one of F or G)

B1: Correct explanation for uniqueness dummy

(b)

B1: Six correct rows (not including A, B and C)

B1: All rows correct (accept blanks for A, B and C)

(c)(i)

M1: All top boxes completed, number generally increasing L to R (condone one "rogue")

A1: CAO - Top boxes

M1: All bottom boxes completed, numbers generally decreasing R to L (condone one "rogue") – condone lack of 0 or 21 for the M mark only

A1: CAO - Bottom boxes

(c)(ii)

A1ft: Correct follow through from their completed top boxes

(c)(iii)

A1: Correct critical activities (A, E, I and L only)

(d)

M1: Plausible histogram (correct up to time 6) with no holes or overhangs (must go to at least 20 on the time axis)

A1: Histogram correct to time 10

A1: Histogram correct from time 10 to time 21

(e)

M1: Explanation involving the need to delay just one of the non-critical activities (must mention one of D, F, G or H) to start after time 10 (oe) – follow through their histogram

A1: Dependent on a correct histogram and correct answer to (c)(i). Correct deduction that it is possible to complete with fewer workers e.g. delay H to start at 10 therefore delay J to start at its late time (or 15) – A0 if mention of delaying activity F

2.

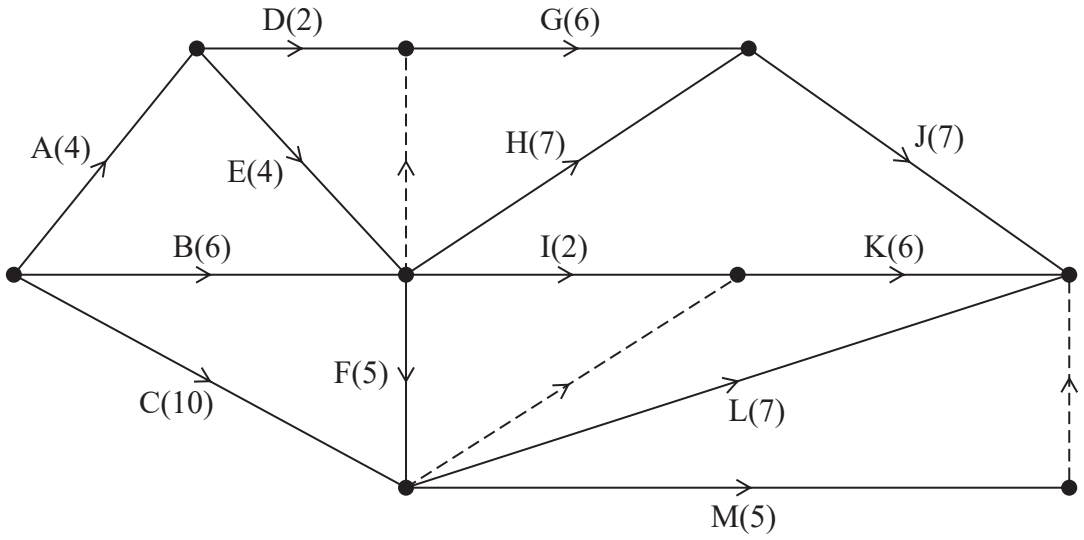


Figure 2

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)

2.

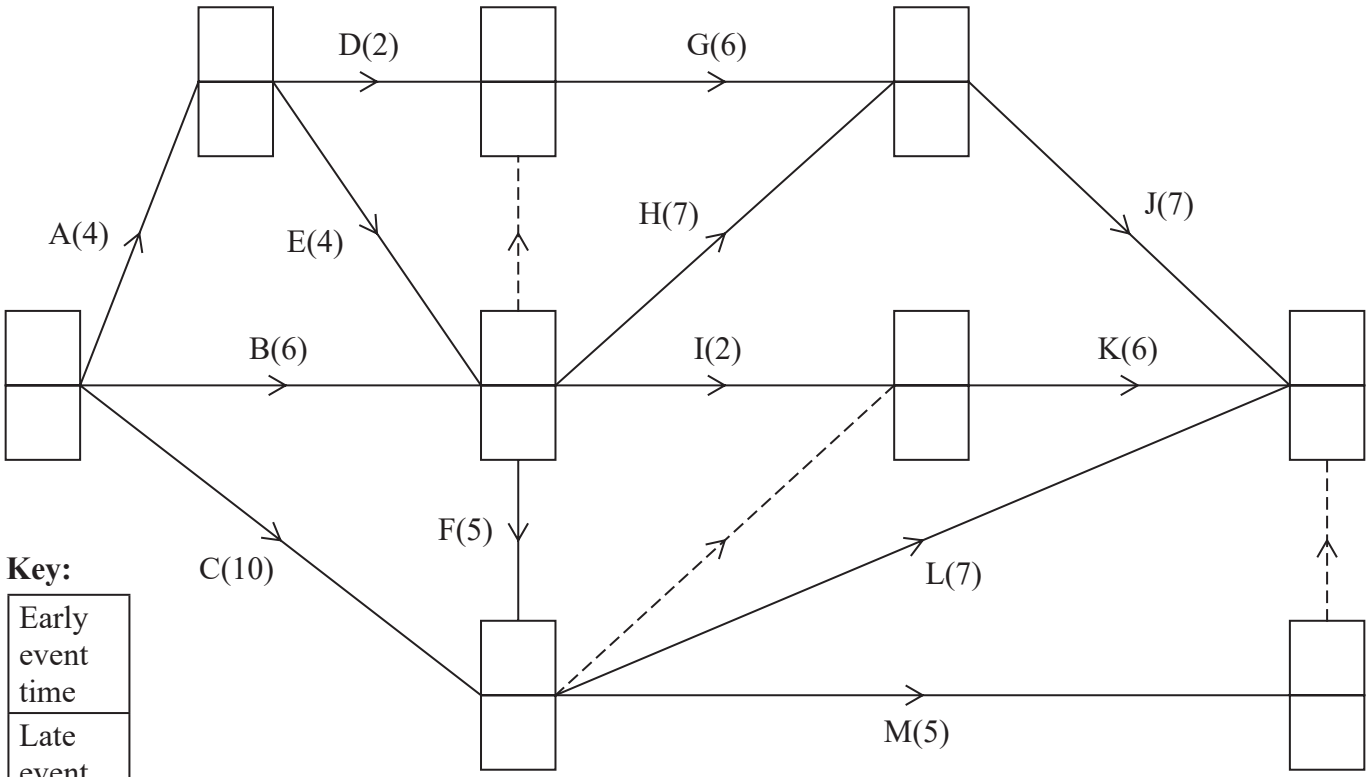
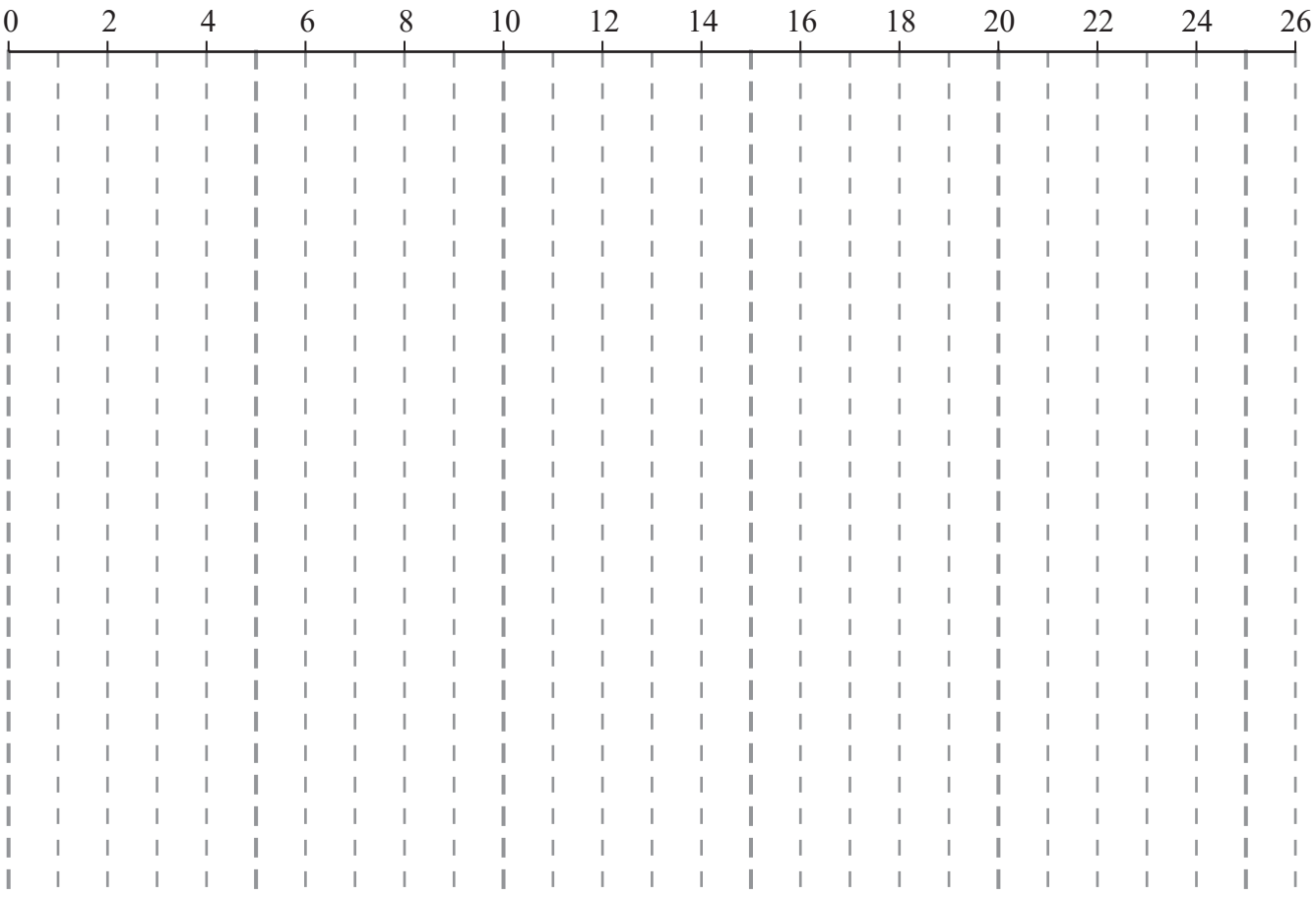


Diagram 1

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

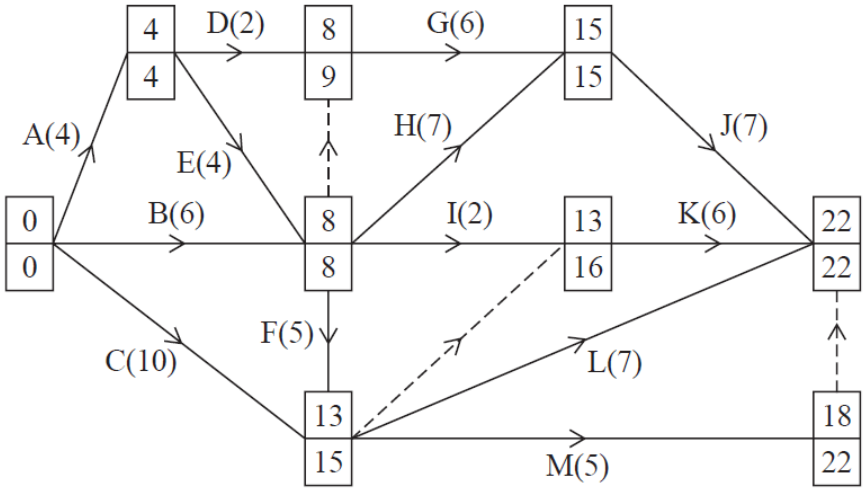
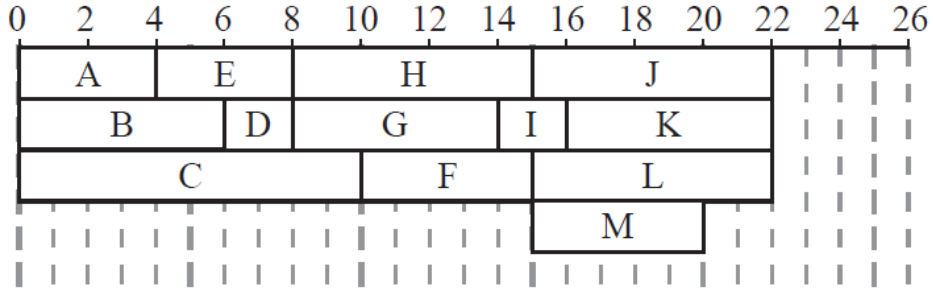
Question 2 continued



Grid 1

(Total for Question 2 is 9 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question	Scheme	Marks	AOs
2(a)		M1 A1 M1 A1	2.1 1.1b 1.1b 1.1b
		(4)	
(b)	$\frac{71}{22} = ...$	M1	1.1b
	…= 3.22… 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 ± 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

7.

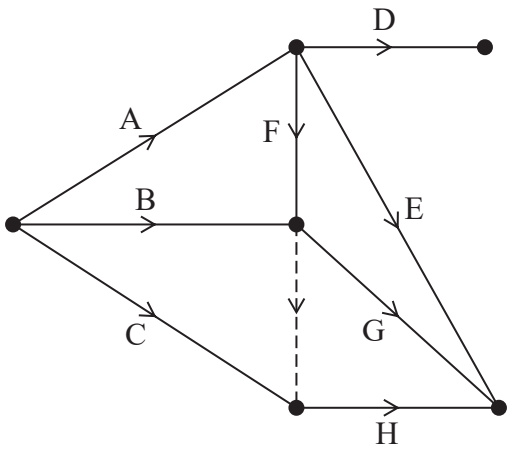


Figure 5

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.

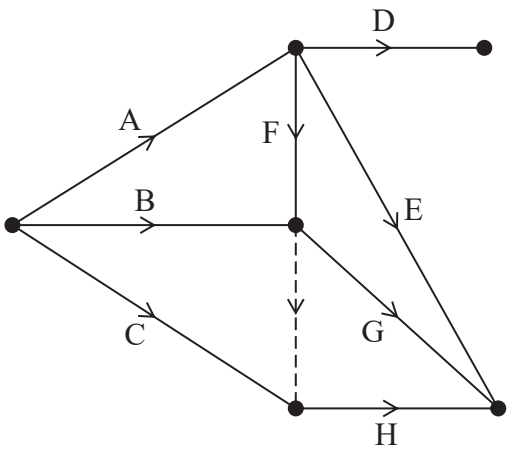
(2)

(Total for Question 7 is 8 marks)

7. (a)

Activity	Immediately preceding activities
A	
B	
C	
D	

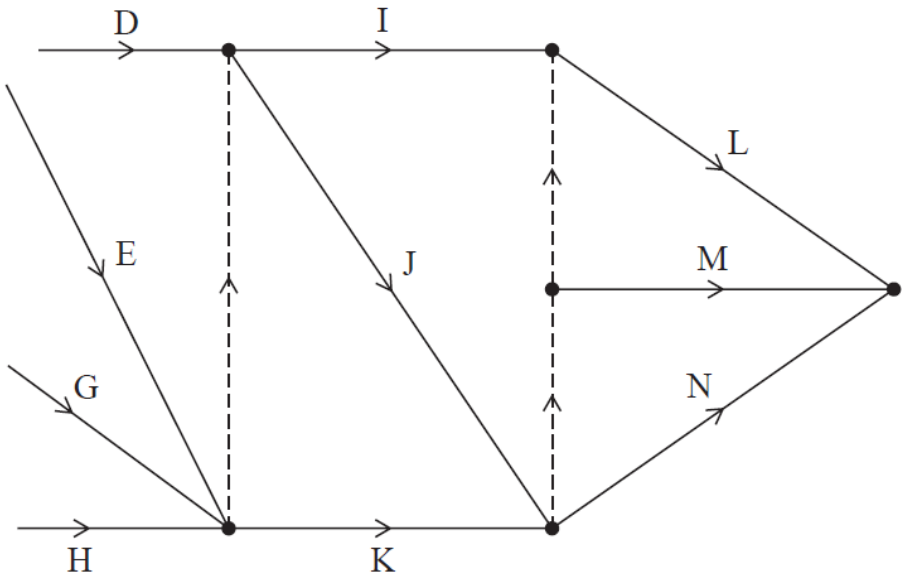
Activity	Immediately preceding activities
E	
F	
G	
H	



DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

<table>
<tr><th>Question</th><th>Scheme</th><th>Marks</th><th>AOs</th></tr>
<tr><td>7(a)</td><td>
<table>
<tr><td>Activity</td><td>Immediately preceding activities</td></tr>
<tr><td>A</td><td>-</td></tr>
<tr><td>B</td><td>-</td></tr>
<tr><td>C</td><td>-</td></tr>
<tr><td>D</td><td>A</td></tr>
<tr><td>E</td><td>A</td></tr>
<tr><td>F</td><td>A</td></tr>
<tr><td>G</td><td>B, F</td></tr>
<tr><td>H</td><td>B, C, F</td></tr>
</table>
</td><td>B1

B1</td><td>1.1b

1.1b</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td>(b)</td><td>e.g.
 
</td><td>M1

A1

A1

A1</td><td>2.1

1.1b

1.1b

1.1b</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td>(c)</td><td>If all activities have the same duration then any critical path must contain 5 activities. All paths that pass-through D have only 4 activities and so therefore D cannot be critical.</td><td>B1
B1</td><td>2.4
2.4</td></tr>
<tr><td></td><td></td><td>(2)</td><td></td></tr>
<tr><td colspan="4">(8 marks)</td></tr>
<tr><td colspan="4">Notes:

(a)
B1: Either row G or H correct
B1: All rows correct (condone blanks in A, B and C rows)</td></tr>
</table>

(b)

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

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 three marks only

(b) M1: At least five activities (labelled on arc), at least two dummies placed

A1: Activities I, J, K and first dummy + arrow dealt with correctly

A1: Activities L, M, N and a second dummy + arrows dealt with correctly

A1: cso – all arrows present for every activity with one finish and exactly three dummies. Note that this is not a unique solution e.g. M and N could be interchanged 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

For reference:

Activity	**I**	**J**	**K**	**L**	**M**	**N**
IPA	D, E, G, H	D, E, G, H	E, G, H	I, J, K	J, K	J, K

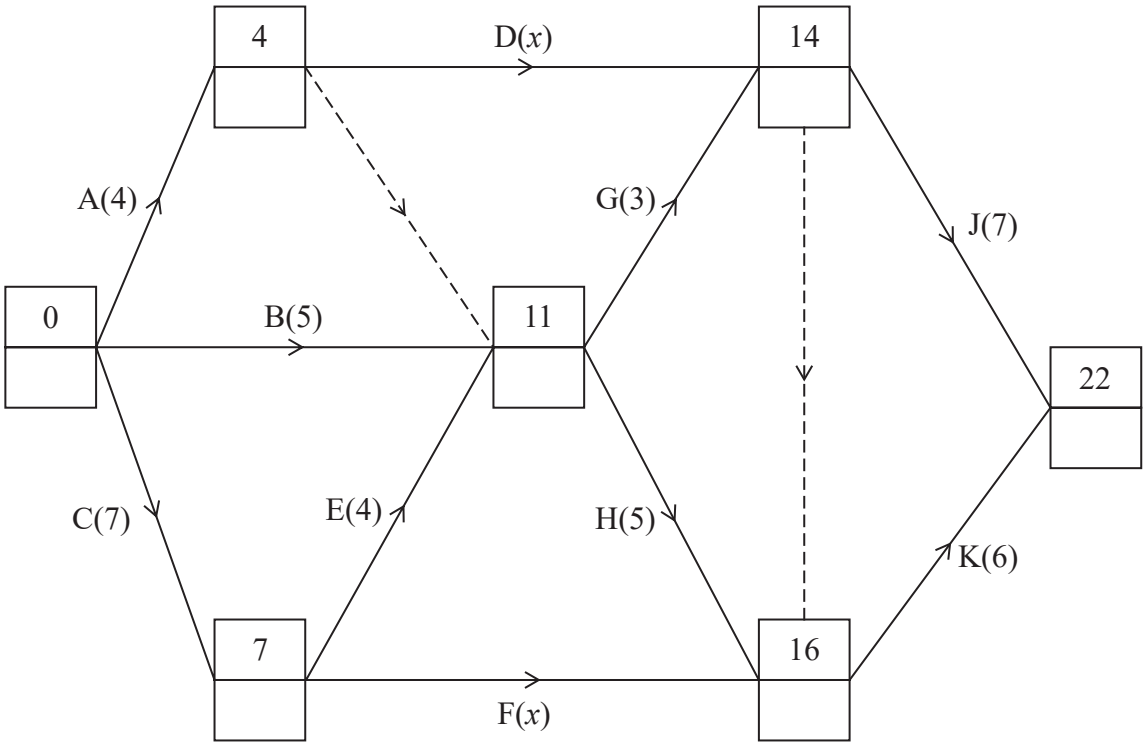
(c)

B1: Explains that all critical paths must contain 5 activities (oe method e.g., attempting a forward and backward pass with each activity having the same duration)

B1: cao that D cannot be critical with mention of all paths through D only contain 4 activities (oe method e.g., showing that the total float on activity D is not zero)

SCB1 – stating or implying that D has a float of 1 (oe) by considering a forward pass (which may or may not be done mathematically) up to at least activity D

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 $4 < x \leqslant m$

(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.

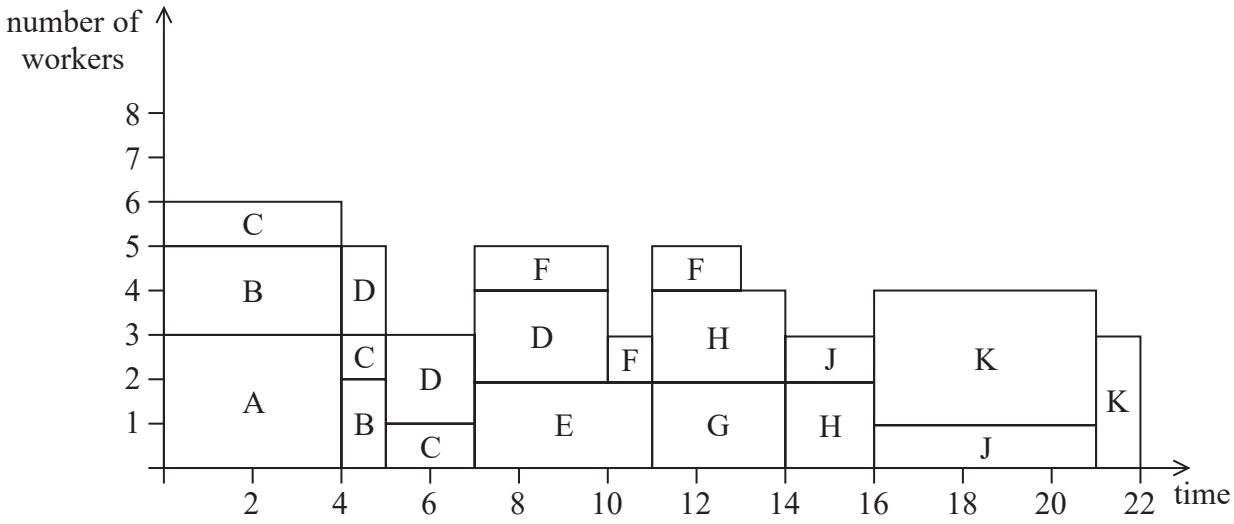


Figure 3

(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)

5.

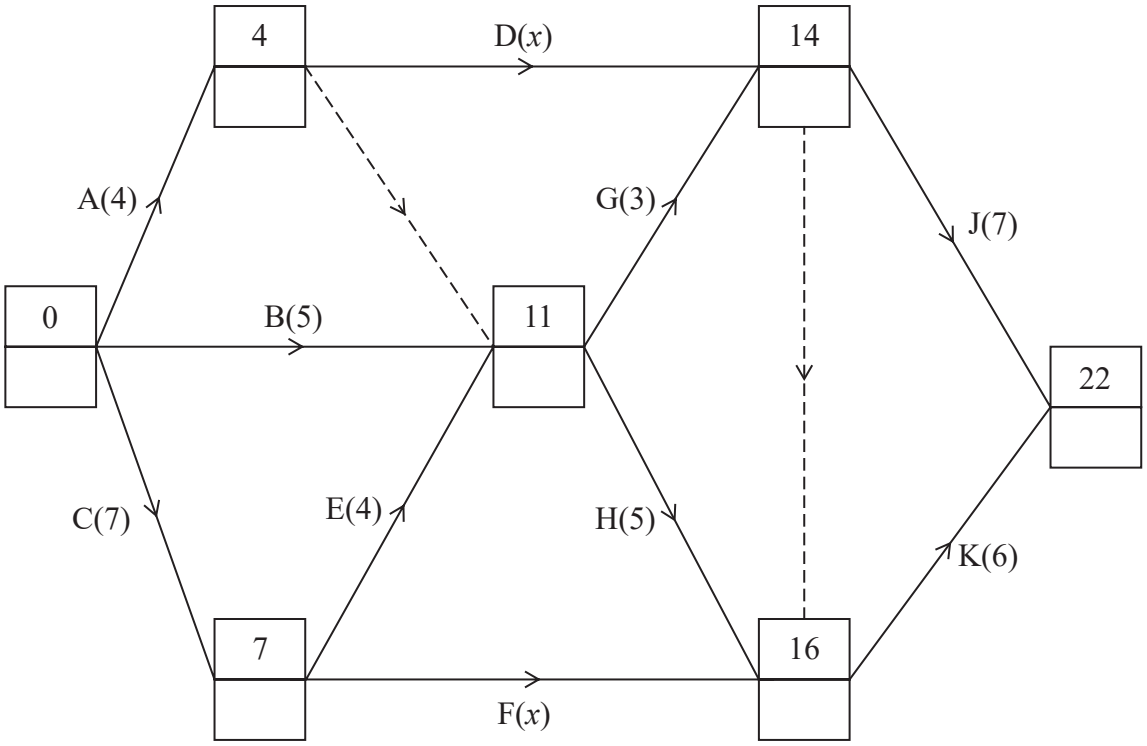
Activity	Immediately preceding activity
A	
B	
C	
D	
E	

Activity	Immediately preceding activity
F	
G	
H	
J	
K	

Table 1

(b)

(c)(i)



Key:

Early event time
Late event time

Diagram 1

(c)(ii)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

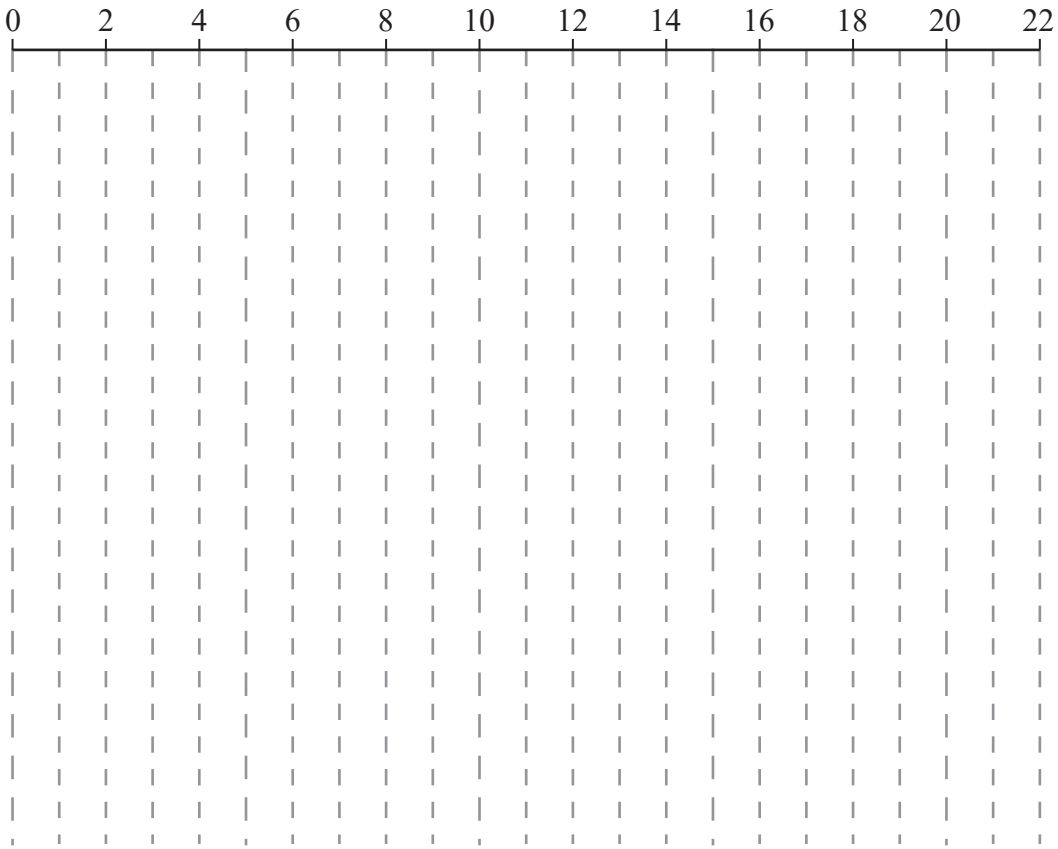
(d)

(e)

Activity	Number of workers
A	
B	
C	
D	
E	

Activity	Number of workers
F	
G	
H	
J	
K	

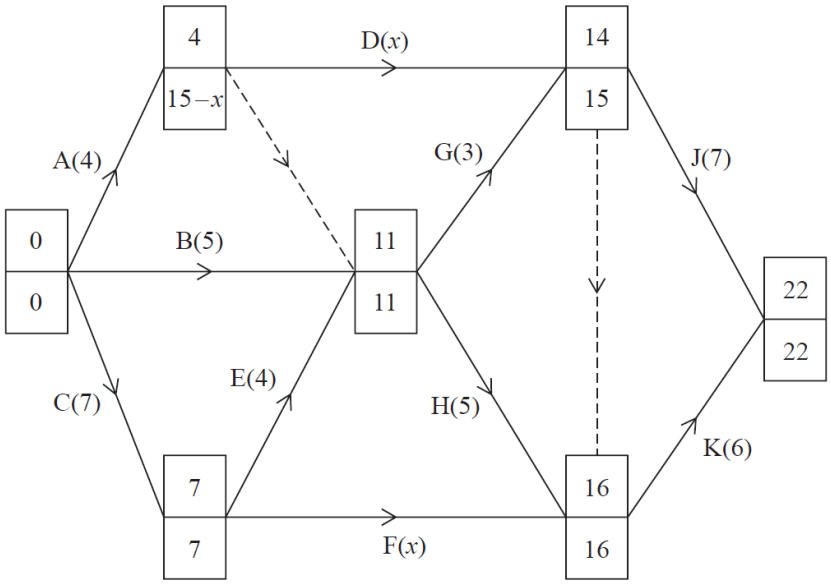
Table 2



Grid 1

(Total for Question 5 is 14 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question	Scheme	Marks	AOs
5(a)	<table><tr><th>Activity</th><th>IPA</th></tr><tr><td>A</td><td>-</td></tr><tr><td>B</td><td>-</td></tr><tr><td>C</td><td>-</td></tr><tr><td>D</td><td>A</td></tr><tr><td>E</td><td>C</td></tr></table> <table><tr><th>Activity</th><th>IPA</th></tr><tr><td>F</td><td>C</td></tr><tr><td>G</td><td>A, B, E</td></tr><tr><td>H</td><td>A, B, E</td></tr><tr><td>J</td><td>D, G</td></tr><tr><td>K</td><td>D, F, G, H</td></tr></table>	**B1** **B1**	1.1b 1.1b
		(2)	
(b)	(m =) 9	**B1**	2.2a
		(1)	
(c)	**(i)**  **(ii)** C, E, H and K must be critical	**M1** **A1** **B1**	1.1b 1.1b 2.2a
		(3)	
(d)	Total float for activity G is 15 – 11 – 3 = 1	**B1**	2.2a
		(1)	

(e)

Activity	Workers
A	3
B	2
C	1
D	2
E	2

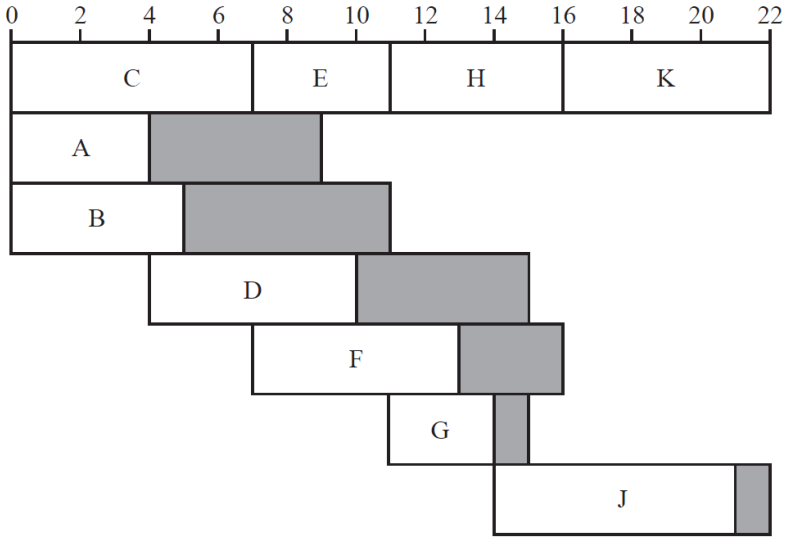
Activity	Workers
F	1
G	2
H	2
J	1
K	3

B1 1.1b

B1 1.1b

(2)

(f) $x = 6$



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 $4 < x \leqslant 9$ or $x \geqslant 9$ but not $x = 9$ or $m \geqslant 9$ 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

3.

Activity	Time taken (days)	Immediately preceding activities
A	5	–
B	8	–
C	4	–
D	14	A
E	10	A
F	3	B, C, E
G	7	C
H	5	D, F, G
I	7	H
J	9	H

The table above shows the activities required for the completion of a building project. For each activity, the table shows the time it takes, in days, and the immediately preceding activities. Each activity requires one worker. The project is to be completed in the shortest possible time.

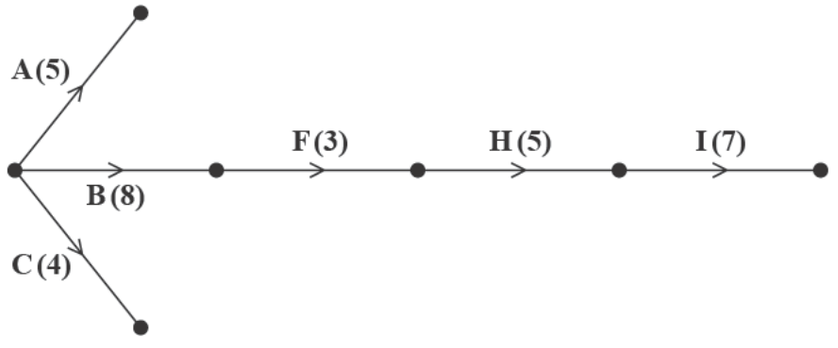


Figure 2

Figure 2 shows a partially completed activity network used to model the project. The activities are represented by the arcs and the number in brackets on each arc is the time taken, in days, to complete the corresponding activity.

(a) Add the missing activities and necessary dummies to Diagram 1 in the answer book.

(3)

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

(3)

(c) State the critical activities.

(1)

At the beginning of the project it is decided that activity G is no longer required.

(d) Explain what effect, if any, this will have on

(i) the shortest completion time of the project if activity G is no longer required,

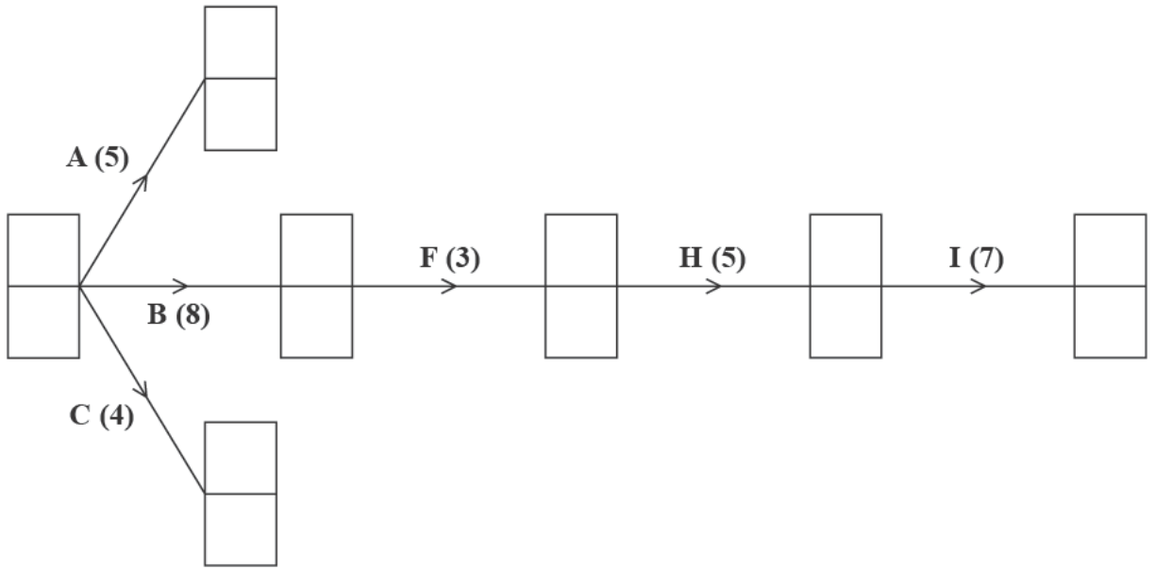
(ii) the timing of the remaining activities.

(3)

(Total for Question 3 is 10 marks)

Leave blank

3.



Key:

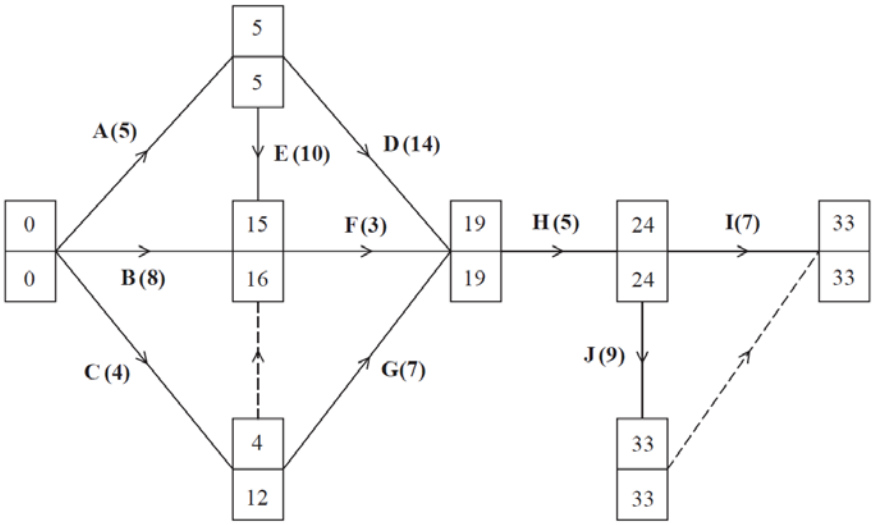
Early event time
Late event time

Diagram 1

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question	Scheme	Marks	AOs
3(a) and (b)		M1 A1 A1 **(3)** M1 M1 A1 **(3)**	1.1b 1.1b 1.1b 1.1b 1.1b 1.1b
(c)	The critical activities are A, D, H and J	B1	1.1b
		(1)	
(d)(i)	No effect (as G is not one of the critical activities)	B1	2.4
(d)(ii)	Activity C is the only affected activity and it can now start 4 days later at time 12 (rather than at time 8) or finish as late as time 16	M1 A1	3.4 1.1b
		(3)	
			(10 marks)

Notes
(a) **M1:** Any three activities of D, E, G, J added together with at least one dummy **A1:** D, E, G and first dummy added correctly (with arrows) i.e. first part of the network correct **A1:** J and second dummy added correctly (with arrows) i.e. second part of the network correct **SC:** If M1A0A0 but only error is any missing arrows then award M1A1A0 **SC:** Award M1A1A0 for a 'correct' diagram with more than two dummies
(b) **M1:** All top boxes complete, numbers increasing in the direction of the arrows – dependent on all four activities D, E, G, J added (bod if not labelled) – condone lack of additional event node for J **M1:** All bottom boxes complete, numbers decreasing in the opposite direction of the arrows – dependent on all four activities D, E, G, J added (bod if not labelled) – condone lack of additional event node for J **A1:** Cso (including diagram) - must contain exactly 8 early and late event times and only two correct dummies placed with one finish – note that some candidates may start with e.g. a dummy at the event before the start of activity I which will affect their early and late event times at this node (both values should be 24))
(c) **B1:** Cao (A, D, H and J)
(d)(i) **B1:** Explanation that there is no effect on the completion time (as G is not critical)
(d)(ii)
M1: Use their model to deduce that C is the (only) activity that is affected **A1:** Correct answer that activity C (only – maybe implicit) can e.g. finish at time 16 or start at time 12 – for this mark the explanation must give a relevant time

3.

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

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

(5)

Every activity shown in the precedence table has the same duration.

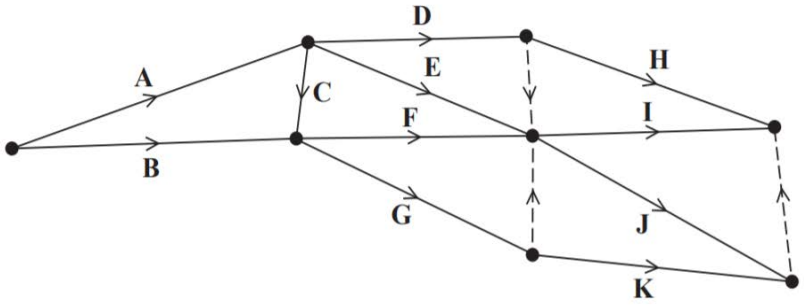
(b) Explain why activity B cannot be critical.

(1)

(c) State which other activities are not critical.

(1)

(Total for Question 3 is 7 marks)

Question	Scheme	Marks	AOs
3(a)		M1 A1 A1 A1 A1	1.1b 1.1b 1.1b 1.1b 1.1b
		(5)	
(b)	Activity F (and/or G) requires activity B and the two activities A and C to be completed before F (and/or G) can begin. The time to complete A and C is double that of B and so B can be delayed waiting for A and C to be completed and so B is therefore not critical.	B1	2.4
		(1)	
(c)	Activities D, E and H	B1	2.2a
		(1)	
			(7 marks)

Notes
In (a) 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. 'G dealt with correctly' requires the correct precedences for this activity, i.e. B and C labelled correctly and leading into the same node and G starting from that node but do not consider the end node for G. **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 corrct place for where a dummy should be) **(a)** **M1:** At least eight activities (labelled on arc), one start, and at least two dummies placed **A1:** Activities A – G dealt with correctly (bod if no arrow on activity C) **A1:** First two required dummies + arrows dealt with correctly **A1:** Activities H – K dealt with correctly (A0 if no arrows on preceding dummies (oe)) **A1:** CSO – Final required dummy + all arrows present and correctly placed with one finish and no additional dummies. Note that the arrow for the final dummy could be reversed. Note that there are several correct viable positions for the final dummy **Note that additional (but unecessary) 'correct' dummies that still maintain precedence for the network should only be penalised with the final A mark if earned** **(b)** **B1:** CAO - some mention of the time required to complete A + C compared with B (for the next activity to begin (either F and/or G)) oe e.g. paths through B have a maximum length of 3 (non-dummy) activities and there is at least one path of length 4 which does not include B so B cannot be critical **OR** the late time for B must be the same as the late time for A + C which is twice the duration of B and therefore B is not critical. Give bod to responses that imply that B and C meet at the same event, but C is also dependent on A (the key point for awarding this mark is that activities A and C imply that B is not critical) **(c)** **B1:** All three correct with no extras (ignore any mention of activity B)

2.

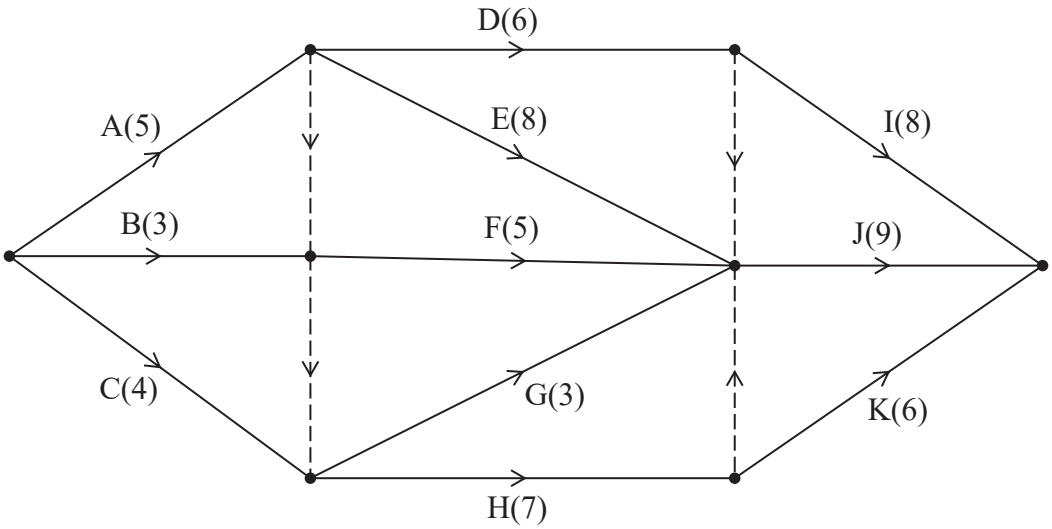


Figure 1

A project is modelled by the activity network shown in Figure 1. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, to complete the corresponding activity. Each activity requires one worker. The project is to be completed in the shortest possible time.

(a) Complete the precedence table in the answer book.

(2)

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

(3)

(c) (i) State the minimum project completion time.

(ii) List the critical activities.

(2)

(d) Calculate the maximum number of hours by which activity H could be delayed without affecting the shortest possible completion time of the project. You must make the numbers used in your calculation clear.

(1)

(e) Calculate a lower bound for the number of workers needed to complete the project in the minimum time. You must show your working.

(2)

(f) Draw a cascade chart for this project on Grid 1 in the answer book.

(3)

(g) Using the answer to (f), explain why it is not possible to complete the project in the shortest possible time using the number of workers found in (e).

(1)

(Total for Question 2 is 14 marks)

2. (a)

Activity	Immediately preceding activities
A	
B	
C	
D	

Activity	Immediately preceding activities
E	
F	
G	
H	

Activity	Immediately preceding activities
I	
J	
K	

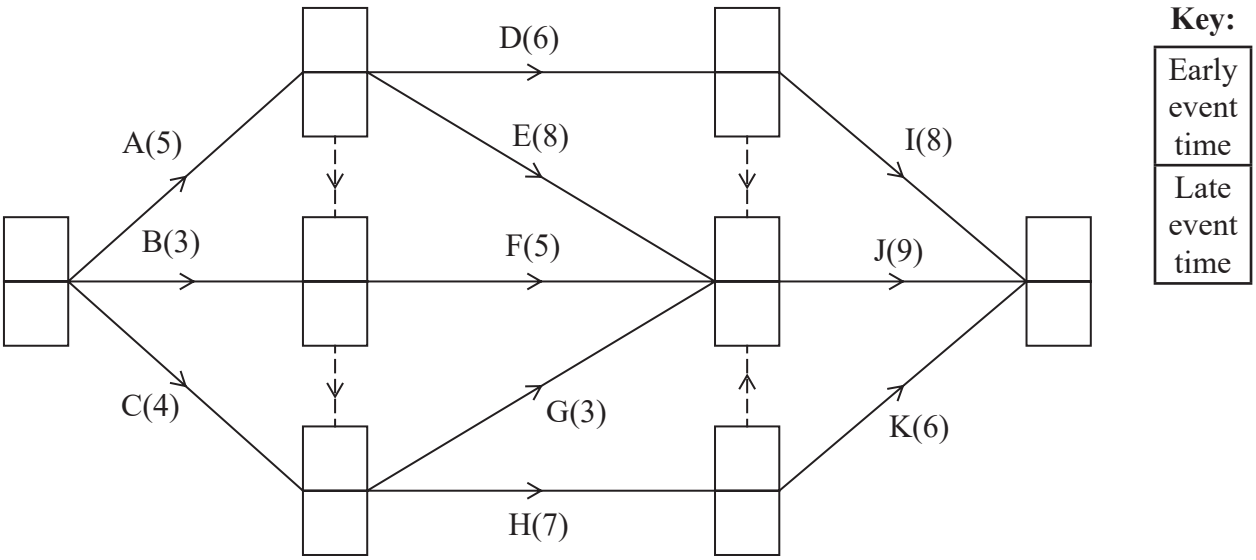
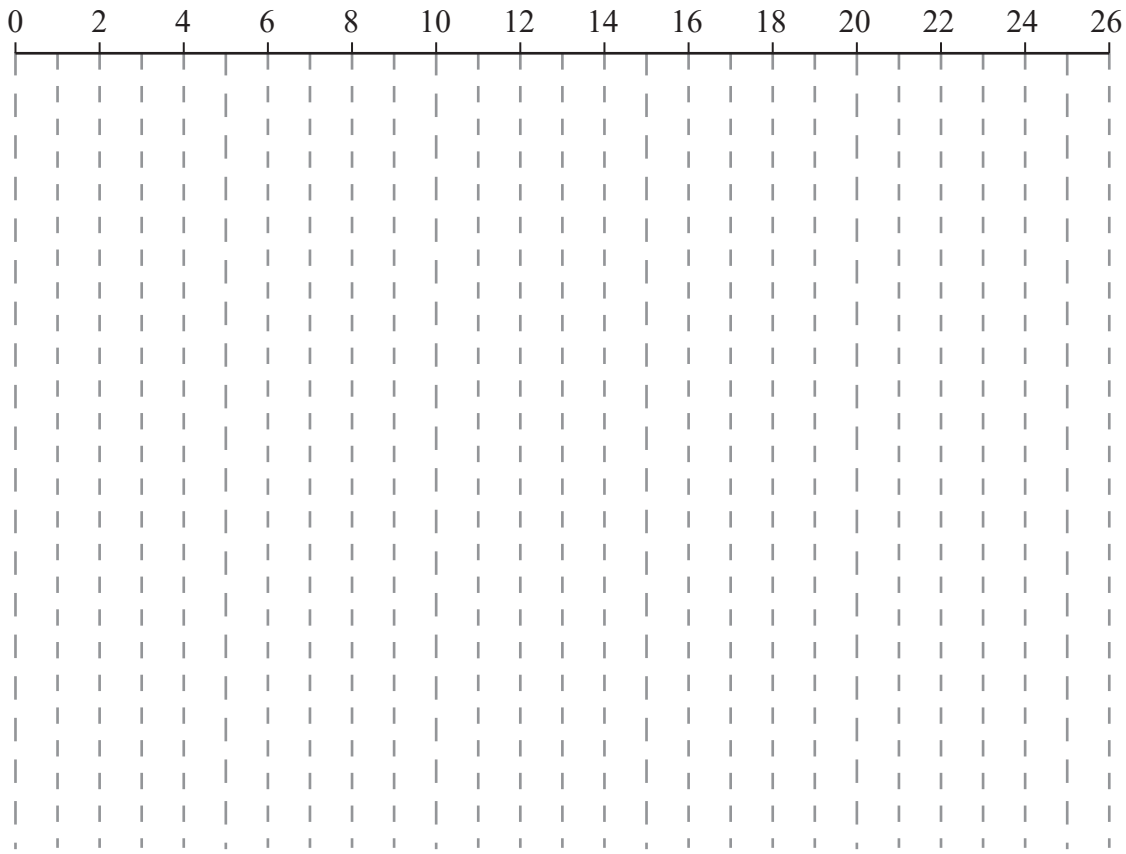


Diagram 1

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

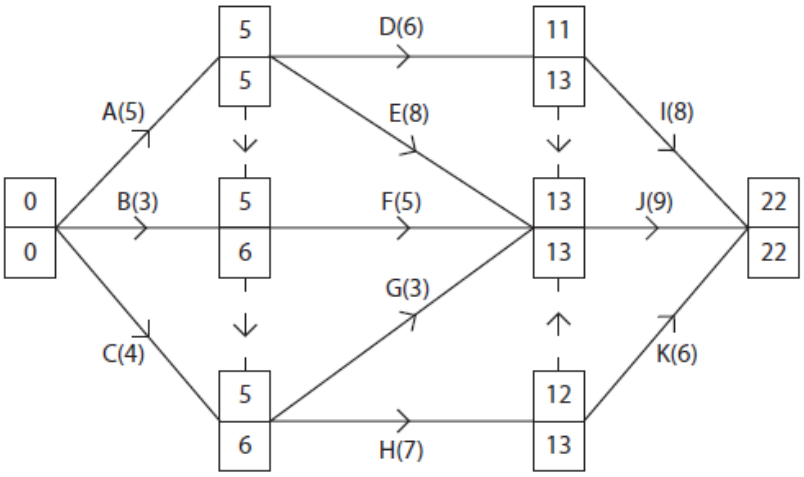
Question 2 continued

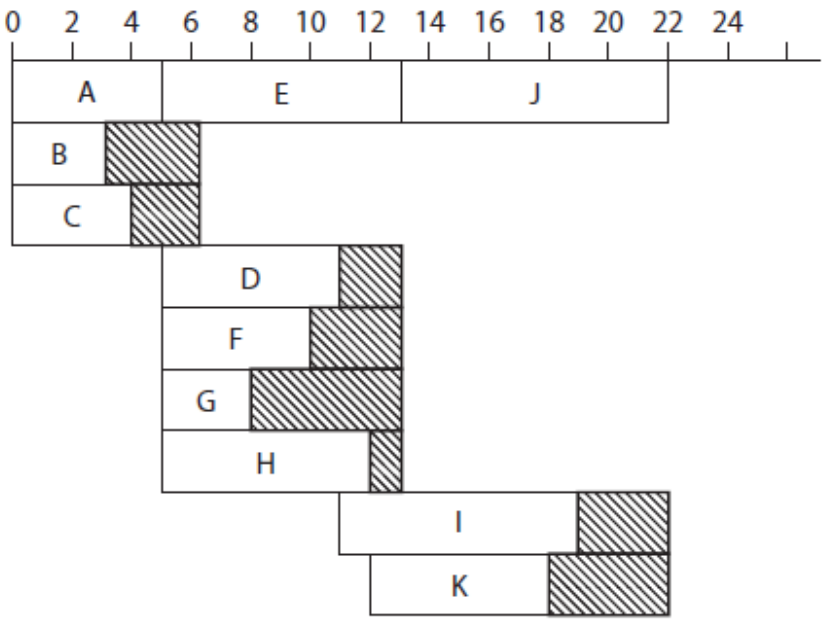


Grid 1

(Total for Question 2 is 14 marks)

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question	Scheme	Marks	AOs
2(a)	<table><tr><th>Activity</th><th>Immediately preceding activity</th></tr><tr><td>A</td><td>-</td></tr><tr><td>B</td><td>-</td></tr><tr><td>C</td><td>-</td></tr><tr><td>D</td><td>A</td></tr></table> <table><tr><th>Activity</th><th>Immediately preceding activity</th></tr><tr><td>E</td><td>A</td></tr><tr><td>F</td><td>A, B</td></tr><tr><td>G</td><td>A, B, C</td></tr><tr><td>H</td><td>A, B, C</td></tr></table> <table><tr><th>Activity</th><th>Immediately preceding activity</th></tr><tr><td>I</td><td>D</td></tr><tr><td>J</td><td>D, E, F, G, H</td></tr><tr><td>K</td><td>H</td></tr></table>	B1 B1	1.1b 1.1b
		(2)	
2(b)		M1 A1 A1	2.1 1.1b 1.1b
		(3)	
2(c)(i)	Minimum project completion time is 22 hours	B1ft	1.1b
2(c)(ii)	Critical activities are A, E and J	B1	1.1b
		(2)	
2(d)	H could be delayed by 13 – 5 – 7 = 1 hour	B1ft	3.4
		(1)	
2(e)	$\frac{5+3+4+...+8+9+6}{22}$ = 2.909... so a lower bound of 3 workers	M1 A1	1.1b 2.2a
		(2)	

2(f)		**M1** **A1** **A1**	2.1 1.1b 1.1b
		(3)	
2(g)	e.g. between times 5 and 13 activities E, D, F, G and H must all be happening. The total time to complete these five activities is 29 hours and 29/8 > 3 so it is not possible to complete with the lower bound of 3 workers e.g. at time 8.5 activities E, D, F and H must be happening so not possible to complete with only 3 workers	**B1**	3.4
		(1)	
			(14 marks)

Notes

(a)
B1: 5 non-empty rows correct (so any 5 of the rows for activities D to K correct)
B1: All 11 rows correct

(b)
M1: All boxes completed, number generally increasing L to R (condone one "rogue") and decreasing R to L (condone one "rogue")
A1: CAO (all top boxes correct)
A1: CAO (all bottom boxes correct)

(c)(i)
B1ft: CAO following through their completed top boxes from **(b)**

(c)(ii)
B1: CAO (A, E and J only)

(d)
B1ft: Correct calculation for their activity H (from **(b)**) – must see all 3 numbers (so just 13 – 12 = 1 is B0)

(e)

M1: (55 to 73 inclusive) / their duration (their answers to **(b)** and **(c)(i)** must be consistent)

A1: Correct deduction of lower bound from a correct calculation – answer of 3 with no working scores no marks in this part

(f)

M1: At least 9 activities including at least 6 floats

A1: All correct critical activities present and 5 non-critical activities correct

A1: All non-critical activities correct

(g)

B1: Correct reasoning that it is not possible to complete the project with only 3 workers – candidates must refer to both times and activities for this mark (as an indication that they have used **(f)**)

2.

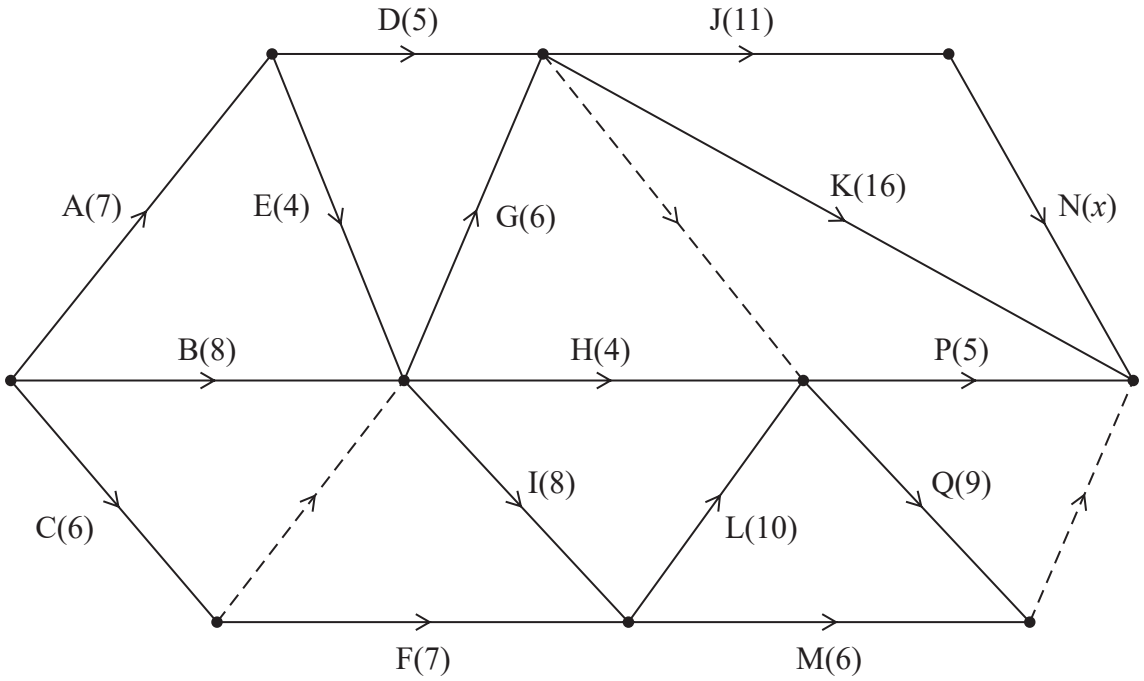


Figure 1

A project is modelled by the activity network shown in Figure 1. 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 exact duration, x, of activity N is unknown, but it is given that $5 < x < 10$

Each activity requires one worker. The project is to be completed in the shortest possible time.

(a) Complete the precedence table in the answer book.

(2)

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

(4)

(c) List the critical activities.

(1)

It is given that activity J can be delayed by up to 4 hours without affecting the shortest possible completion time of the project.

(d) Determine the value of x. You must make the numbers used in your calculation clear.

(1)

(e) Draw a cascade chart for this project on Grid 1 in the answer book.

(4)

(Total for Question 2 is 12 marks)

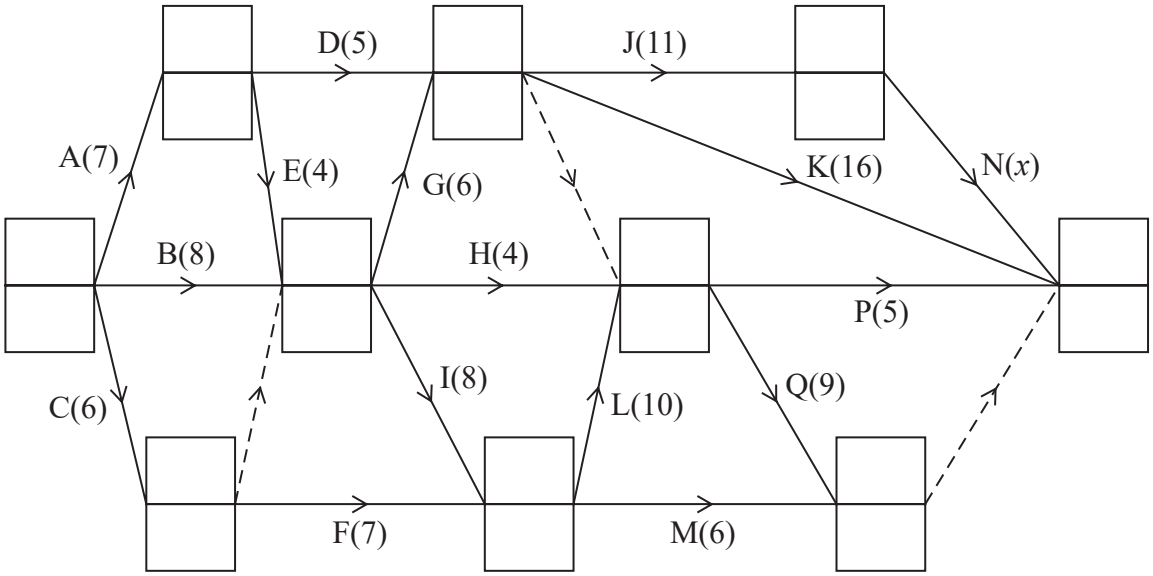
2. (a)

Activity	Immediately preceding activities
A	
B	
C	
D	
E	
F	

Activity	Immediately preceding activities
G	
H	
I	
J	
K	
L	

Activity	Immediately preceding activities
M	
N	
P	
Q	

(b)



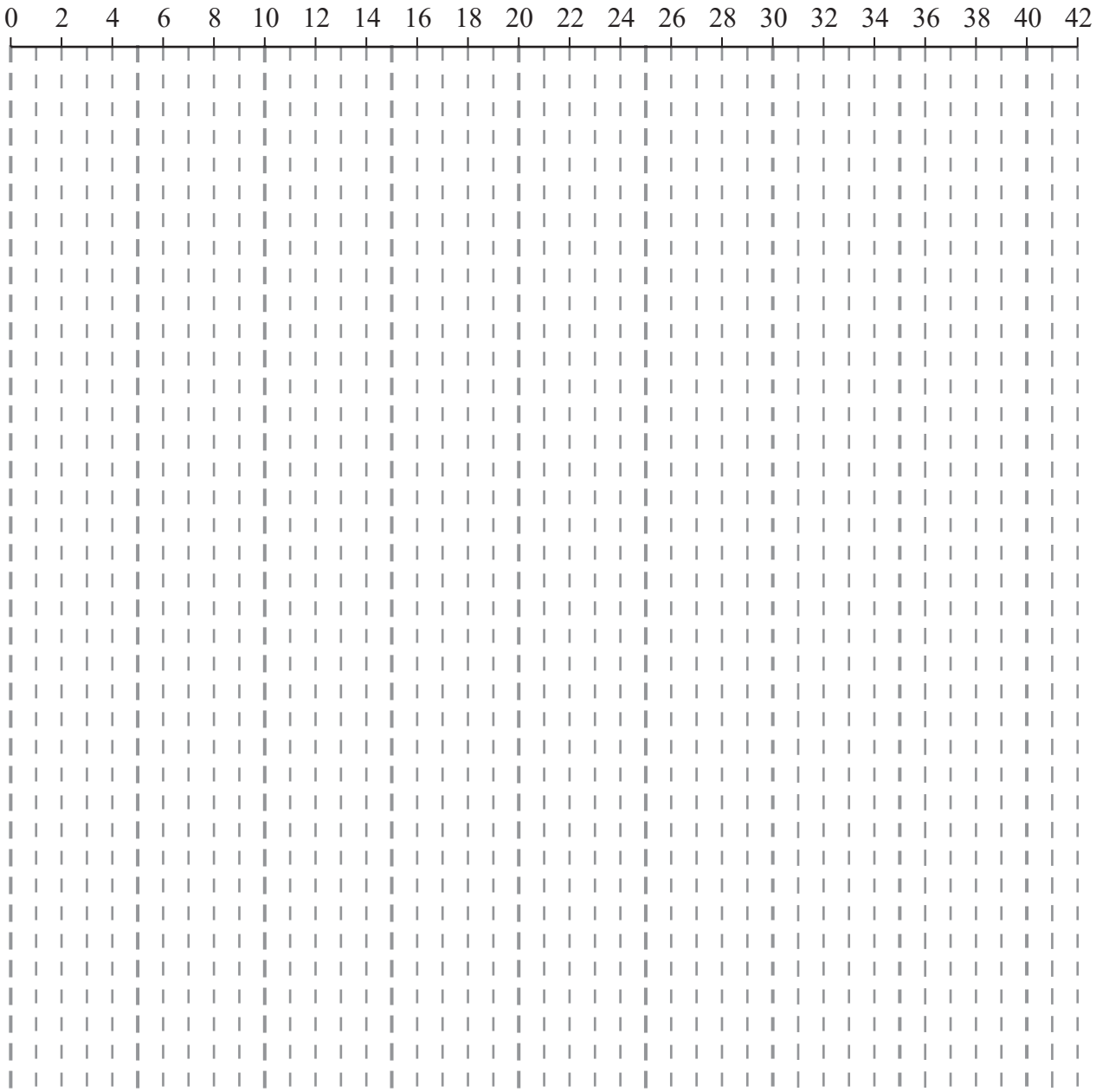
Key:

Early event time
Late event time

Diagram 1

DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA
DO NOT WRITE IN THIS AREA

Question 2 continued



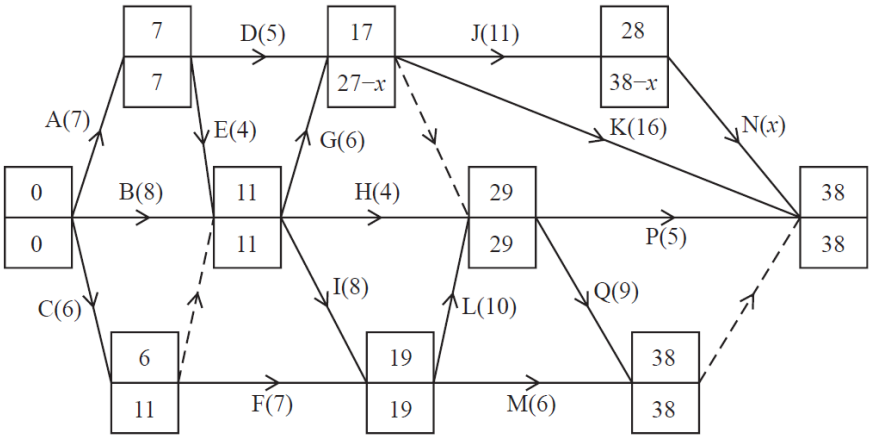
Grid 1

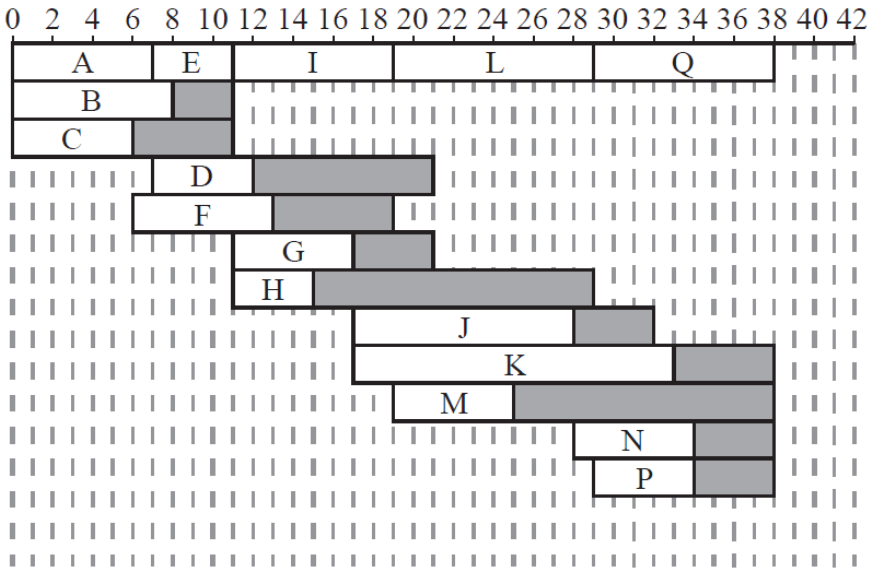
(Total for Question 2 is 12 marks)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question	Scheme	Marks	AOs
2(a)	<table><tr><th>Activity</th><th>Immediately preceding activities</th></tr><tr><td>A</td><td>-</td></tr><tr><td>B</td><td>-</td></tr><tr><td>C</td><td>-</td></tr><tr><td>D</td><td>A</td></tr><tr><td>E</td><td>A</td></tr><tr><td>F</td><td>C</td></tr></table> <table><tr><th>Activity</th><th>Immediately preceding activities</th></tr><tr><td>G</td><td>B, C, E</td></tr><tr><td>H</td><td>B, C, E</td></tr><tr><td>I</td><td>B, C, E</td></tr><tr><td>J</td><td>D, G</td></tr><tr><td>K</td><td>D, G</td></tr><tr><td>L</td><td>F, I</td></tr></table> <table><tr><th>Activity</th><th>Immediately preceding activities</th></tr><tr><td>M</td><td>F, I</td></tr><tr><td>N</td><td>J</td></tr><tr><td>P</td><td>D, G, H, L</td></tr><tr><td>Q</td><td>D, G, H, L</td></tr></table>	B1 B1	1.1b 1.1b
		(2)	
2(b)		M1 A1 M1 A1	2.1 1.1b 2.1 1.1b
		(4)	
2(c)	Critical activities are A, E, I, L and Q	B1	2.2a
		(1)	
2(d)	$(38-x)-17-11=4 \Rightarrow x=6$	B1	3.4
		(1)	

Question	Scheme	Marks	AOs
2(e)		M1 A1 A1 A1	2.1 1.1b 1.1b 1.1b
		(4)	
			(12 marks)

Notes:

(a)

B1: 8 rows correct (not including A, B, C)

B1: All 16 rows correct

(b)

M1: All top boxes completed, number generally increasing L to R (condone one "rogue")

A1: cao (top boxes)

M1: All bottom boxes completed, number generally decreasing R to L (condone one "rogue")

A1: cao (bottom boxes)

(c)

B1: cao

(d)

B1: Correct calculation for x

(e)

M1: At least 10 activities including at least 6 floats

A1: All correct critical activities present and 5 non-critical activities correct

A1: Any 8 non-critical activities correct

A1: cso

2.

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

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

(5)

(b) Explain why it is necessary to draw a dummy from the end of activity A.

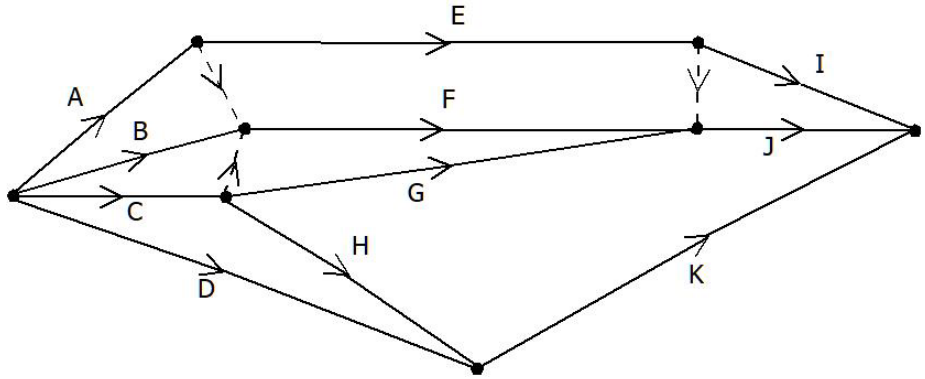
(1)

Every activity shown in the precedence table has the same duration.

(c) State which activity cannot be critical, justifying your answer.

(2)

(Total for Question 2 is 8 marks)

Qu	Scheme	Marks	AOs
2(a)		M1 A1 A1 A1 A1	1.1b 1.1b 1.1b 1.1b 1.1b
		(5)	
(b)	e.g. Activity E is preceded by activity A only, but activity F is preceded by activity B (and/or C) as well as activity A	B1	2.4
		(1)	
(c)	Activity D as this is the only activity on a path from start to finish of which contains only two activities. All other activities appear on at least one longer path	M1 A1	3.1b 3.4
		(2)	
			(8 marks)

Notes for Question 2

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

If an arc is not labelled, for example, if the arc for activity D 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 third A mark on the bod. If two or more arcs are not labelled then mark according to the scheme. Assume that a solid line is an activity which has not been labelled rather than a dummy (even if in the correct place for where a dummy should be)

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

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

a1A1: Activities A, B, C, D, E, G and H dealt with correctly

a2A1: Activity F dealt with correctly and first two dummies & correct arrows dealt with correctly

a3A1: Activities I, J, K and final dummy dealt with correctly.

a4A1: cso All arrows present and correctly placed with one finish and no additional dummies

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**

b1B1: Reference to E depends on A only, while F depends on A and B (and/or C). So must mention activities A, E, F and at least one of B and C

c1M1: cao - Activity D **only** – if more than one activity stated then M0

c1A1: Correct reasoning. Explain that the path/route through D is the only one containing two activities **or** that all other routes/paths have 3 activities. Or mention activities C, H and K **and** that C and H together take 'longer' to finish than D