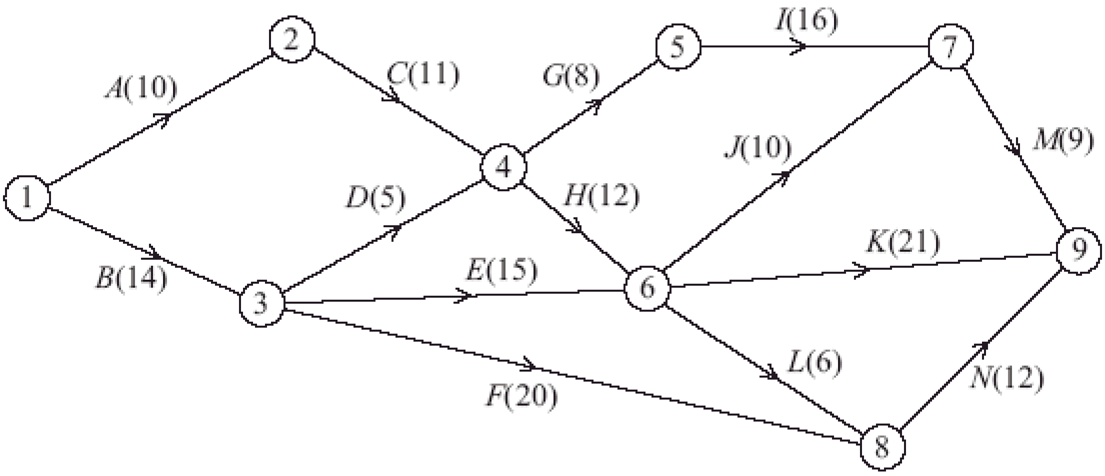
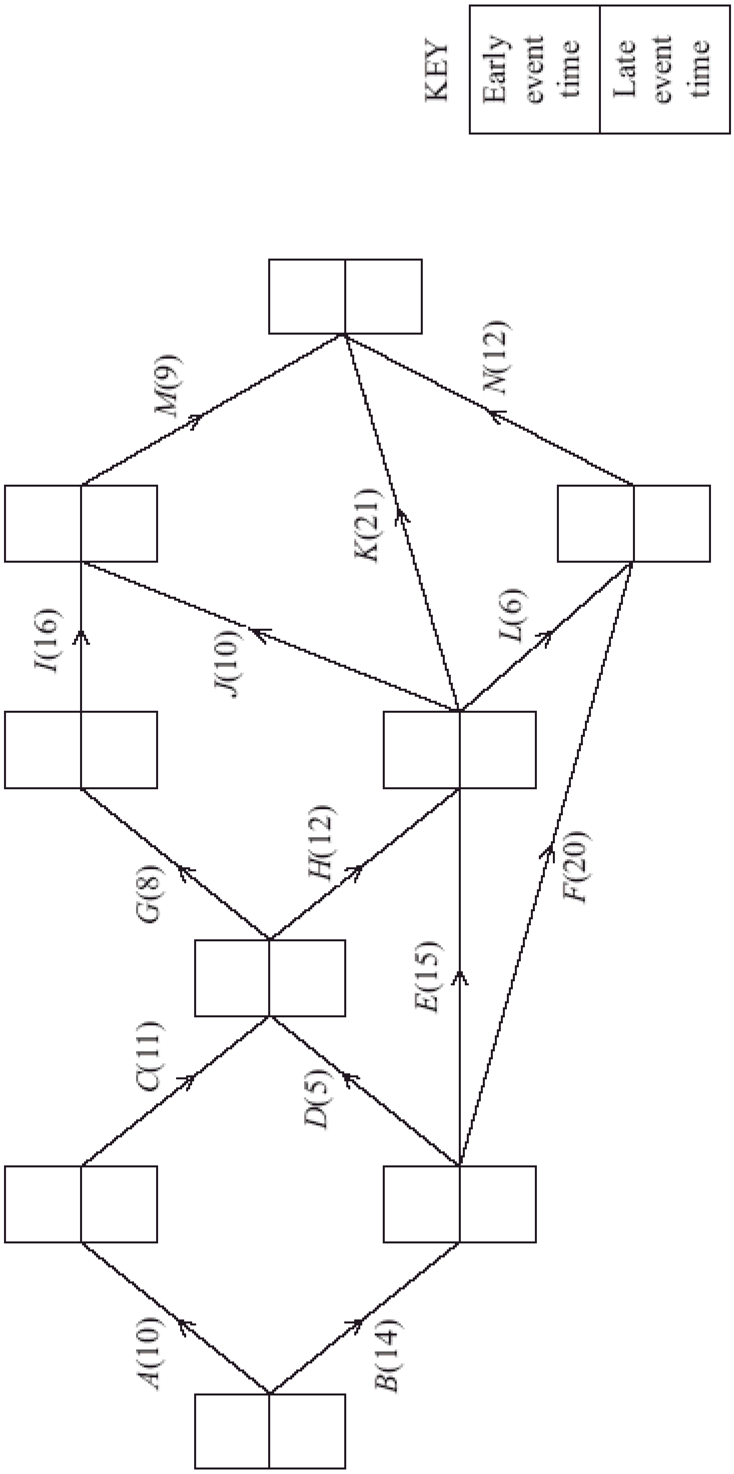
1.



An engineering project is modelled by the activity network shown in the figure above. The activities are represented by the arcs. The number in brackets on each arc gives the time, in days, to complete the activity. Each activity requires one worker. The project is to be completed in the shortest time.

(a) Calculate the early time and late time for each event. Write these in the boxes in the diagram below.



(4)

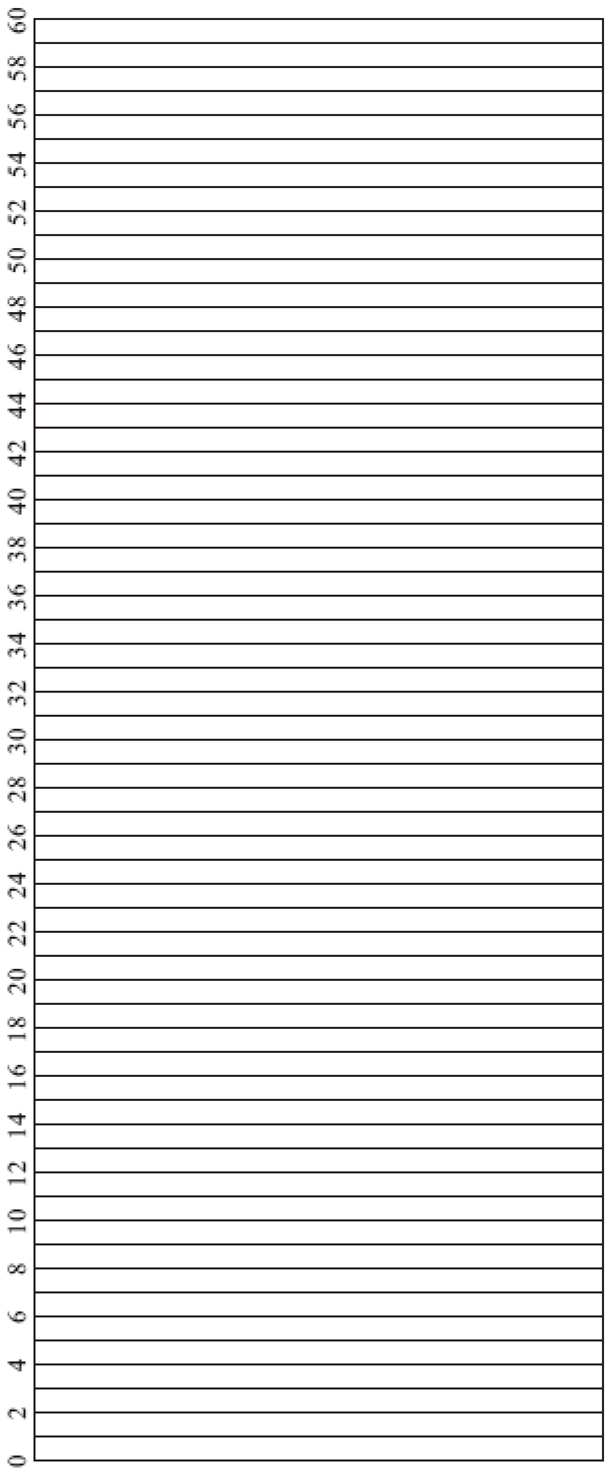
(b) State the critical activities.

(1)

(c) Find the total float on activities *D* and *F*. You must show your working.

(3)

(d) On the below, draw a cascade (Gantt) chart for this project.



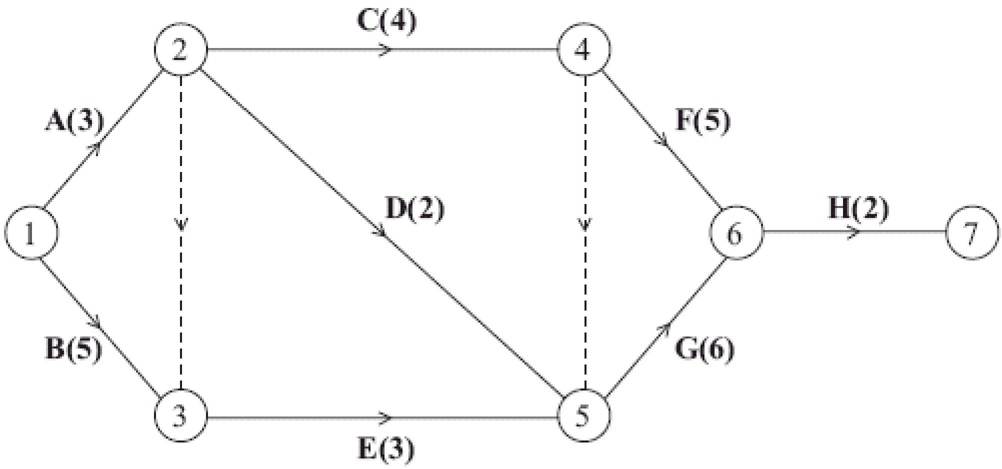
(4)

The chief engineer visits the project on day 15 and day 25 to check the progress of the work. Given that the project is on schedule,

(e) which activities **must** be happening on each of these two days?

(3)
(Total 15 marks)

2.



The diagram above is the activity network relating to a building project. The number in brackets on each arc gives the time taken, in days, to complete the activity.

(a) Explain the significance of the dotted line from event (2) to event (3).

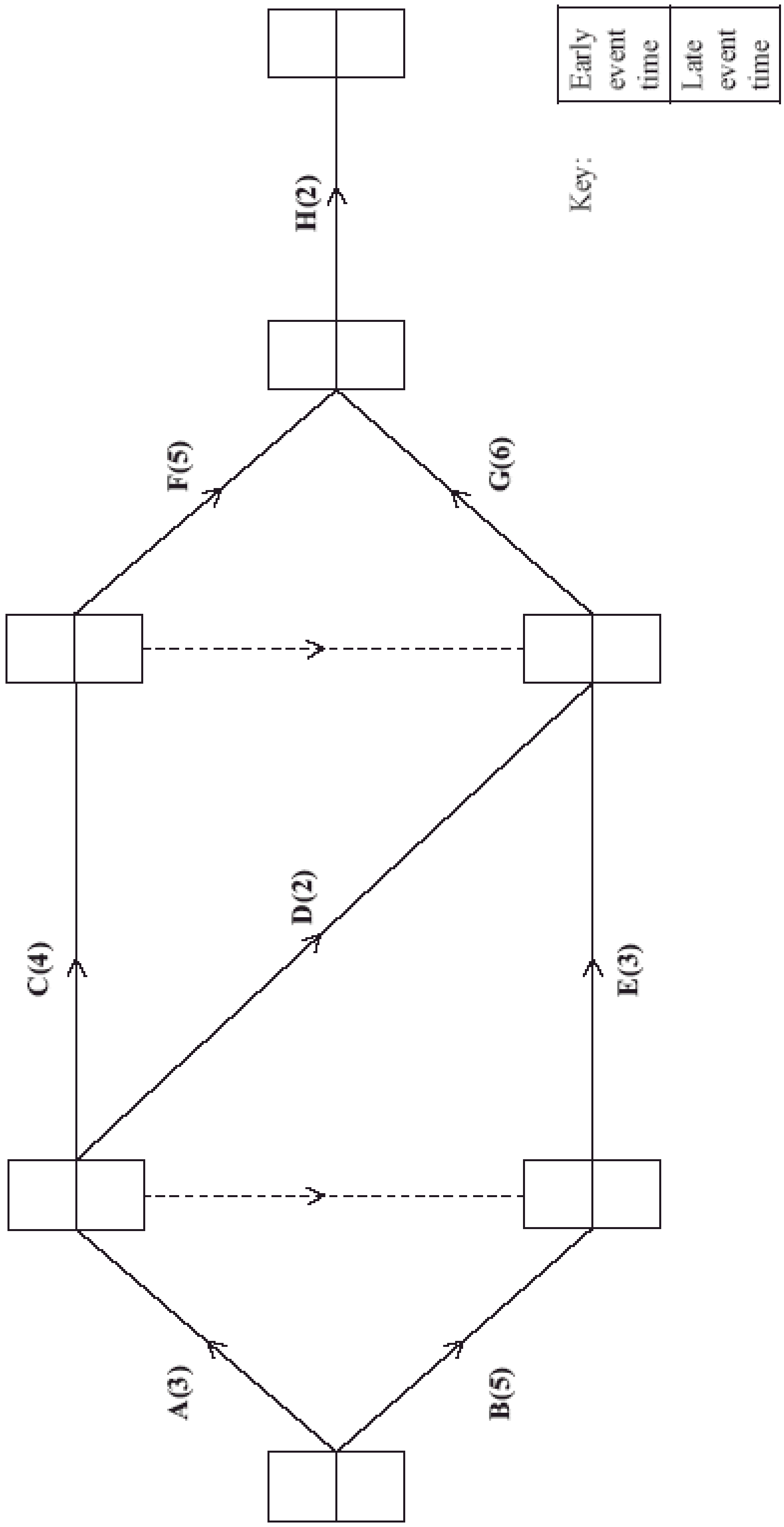
(2)

(b) Complete the precedence table below.

Event	Immediately preceding activity
A	–
B	–
C	
D	
E	
F	
G	
H	

(3)

(c) Calculate the early time and the late time for each event, showing them on the diagram below.

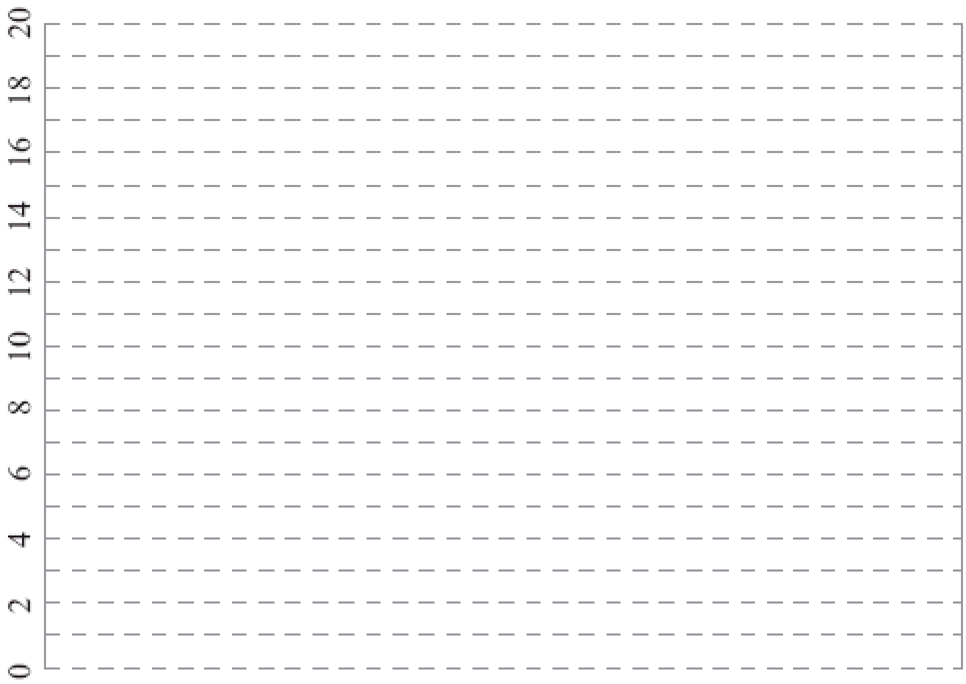


(4)

(d) Determine the critical activities and the length of the critical path.

(2)

(e) On the grid below, draw a cascade (Gantt) chart for the project.



(4)
(Total 15 marks)

3.

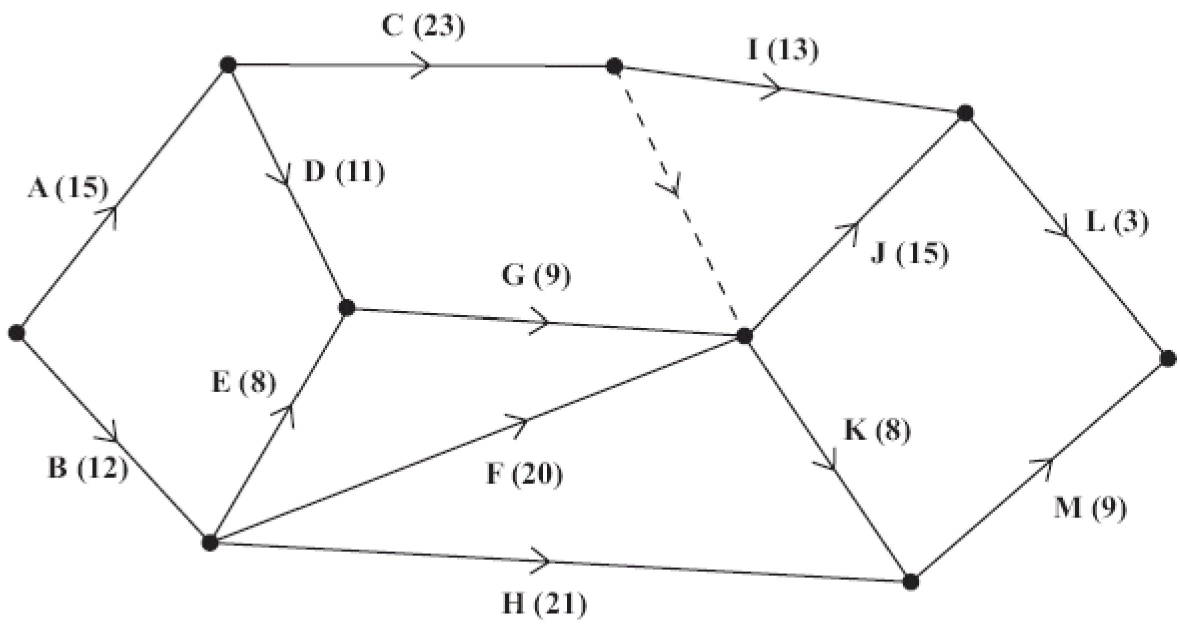


Figure 1

A construction 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 days, to complete the activity. Each activity requires one worker. The project is to be completed in the shortest possible time.

(a) Complete Figure 2 below, showing the early and late event times.

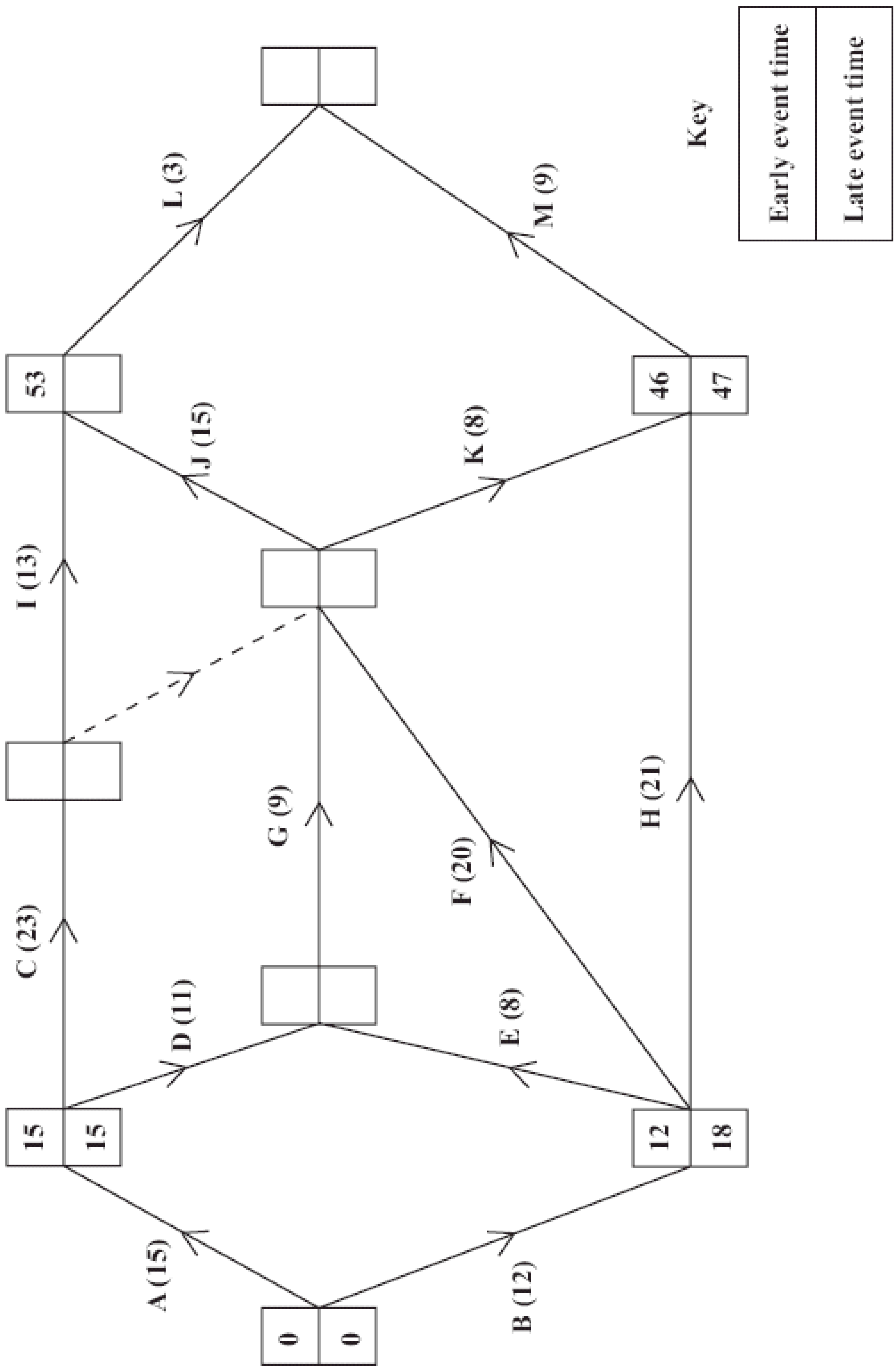


Figure 2

(4)

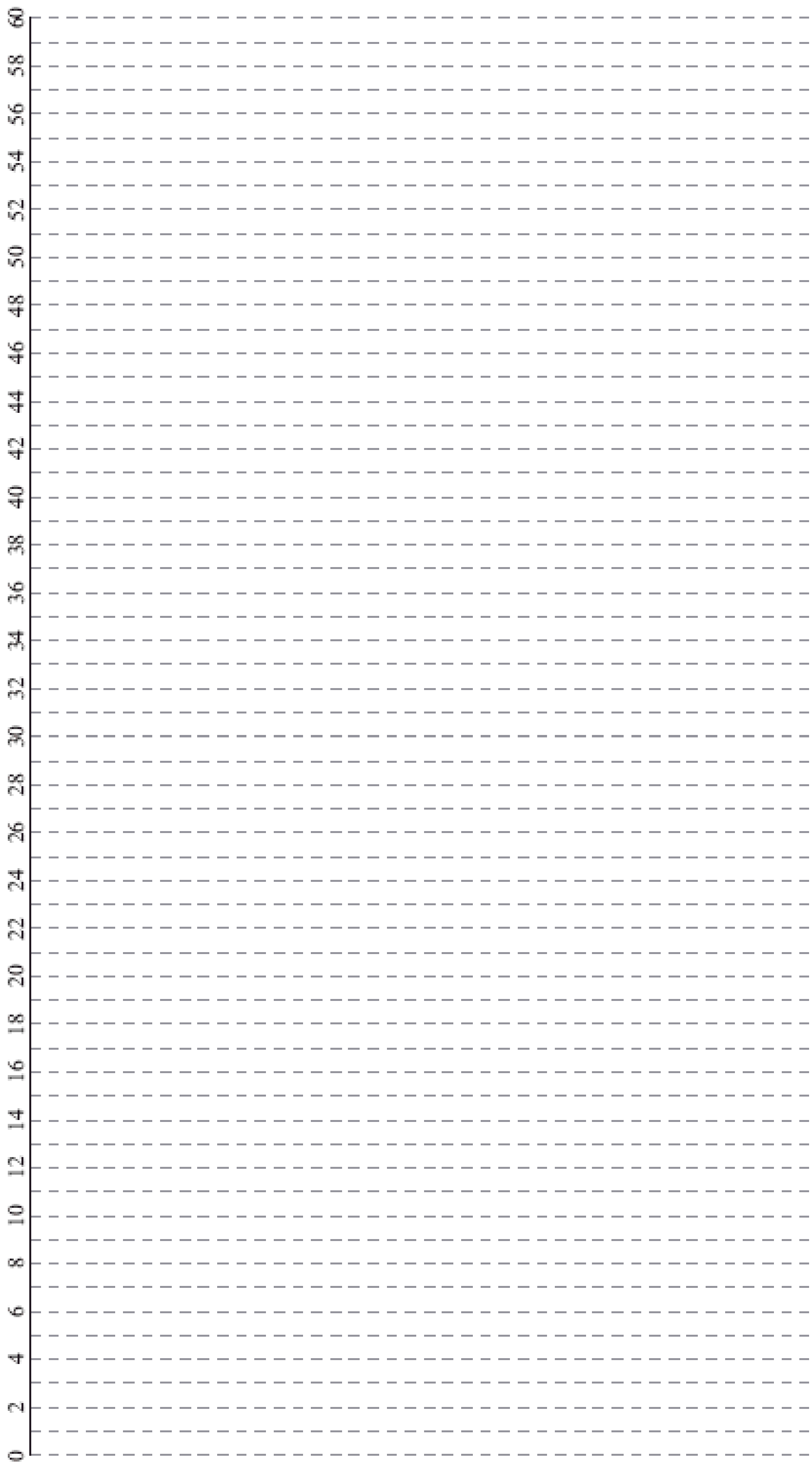
(b) State the critical activities.

(1)

(c) Find the total float for activities M and H. You **must** make the numbers you use in your calculations clear.

(3)

(d) On the grid below, draw a cascade (Gantt) chart for this project.



(4)

An inspector visits the project at 1pm on days 16 and 31 to check the progress of the work.

(e) Given that the project is on schedule, which activities **must** be happening on each of these days?

(3)
(Total 15 marks)

4.

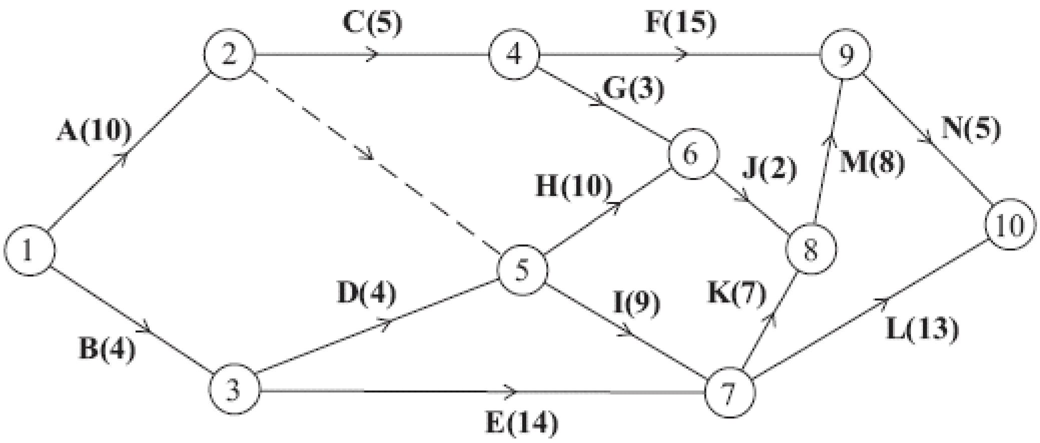


Figure 1

The network in Figure 1 shows the activities involved in a process. The activities are represented by the arcs. The number in brackets on each arc gives the time, in days, taken to complete the activity.

(a) Calculate the early time and the late time for each event, showing them on Figure 2.

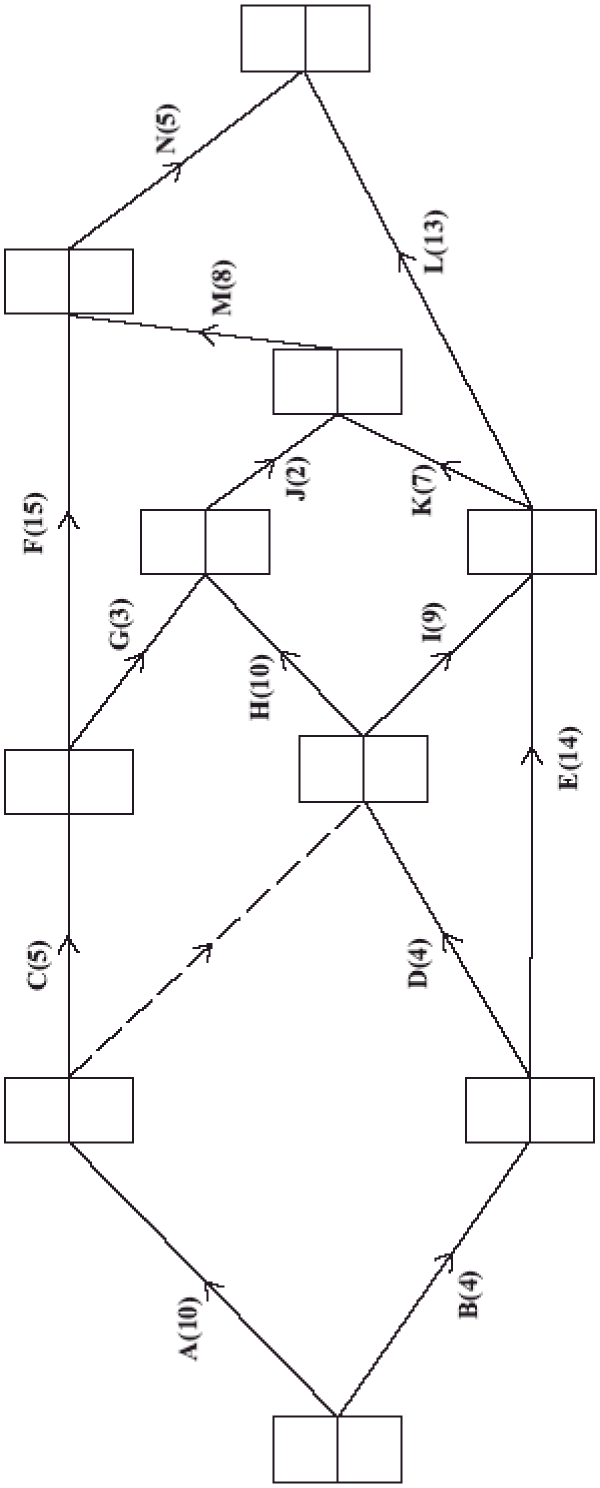


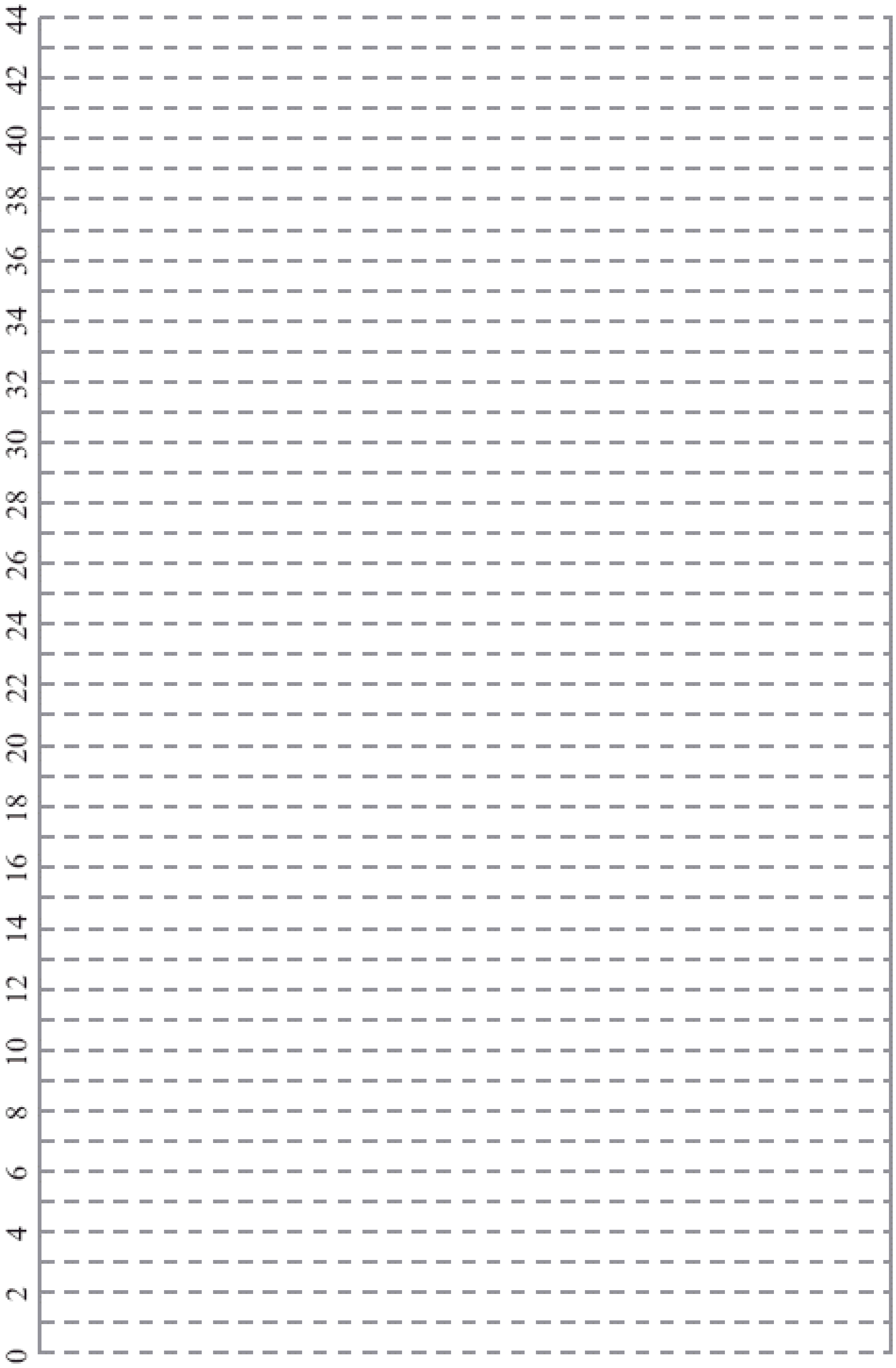
Figure 2

(4)

(b) Determine the critical activities and the length of the critical path.
(3)

(c) Calculate the total float on activities F and G. You **must** make the numbers you used in your calculation clear.
(3)

(d) On the grid below, draw a cascade (Gantt) chart for the process.



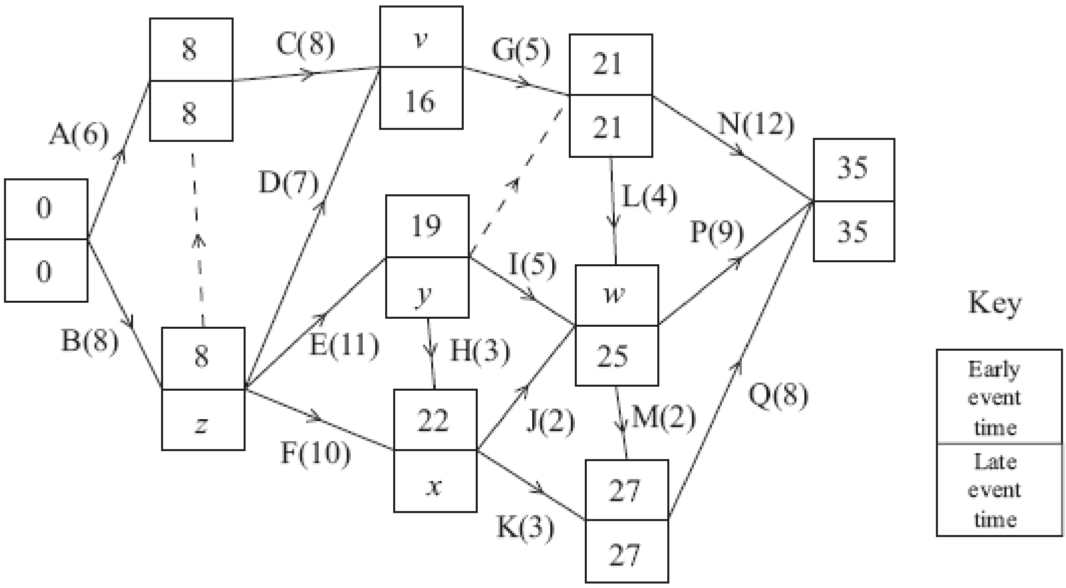
(4)

Given that each task requires just one worker,

(e) use your cascade chart to determine the minimum number of workers required to complete the process in the minimum time. Explain your reasoning clearly.

(2)
(Total 16 marks)

5.



The network above shows the activities that need to be undertaken to complete a building project. Each activity is represented by an arc. The number in brackets is the duration of the activity in days. The early and late event times are shown at each vertex.

(a) Find the values of v, w, x, y and z.

(3)

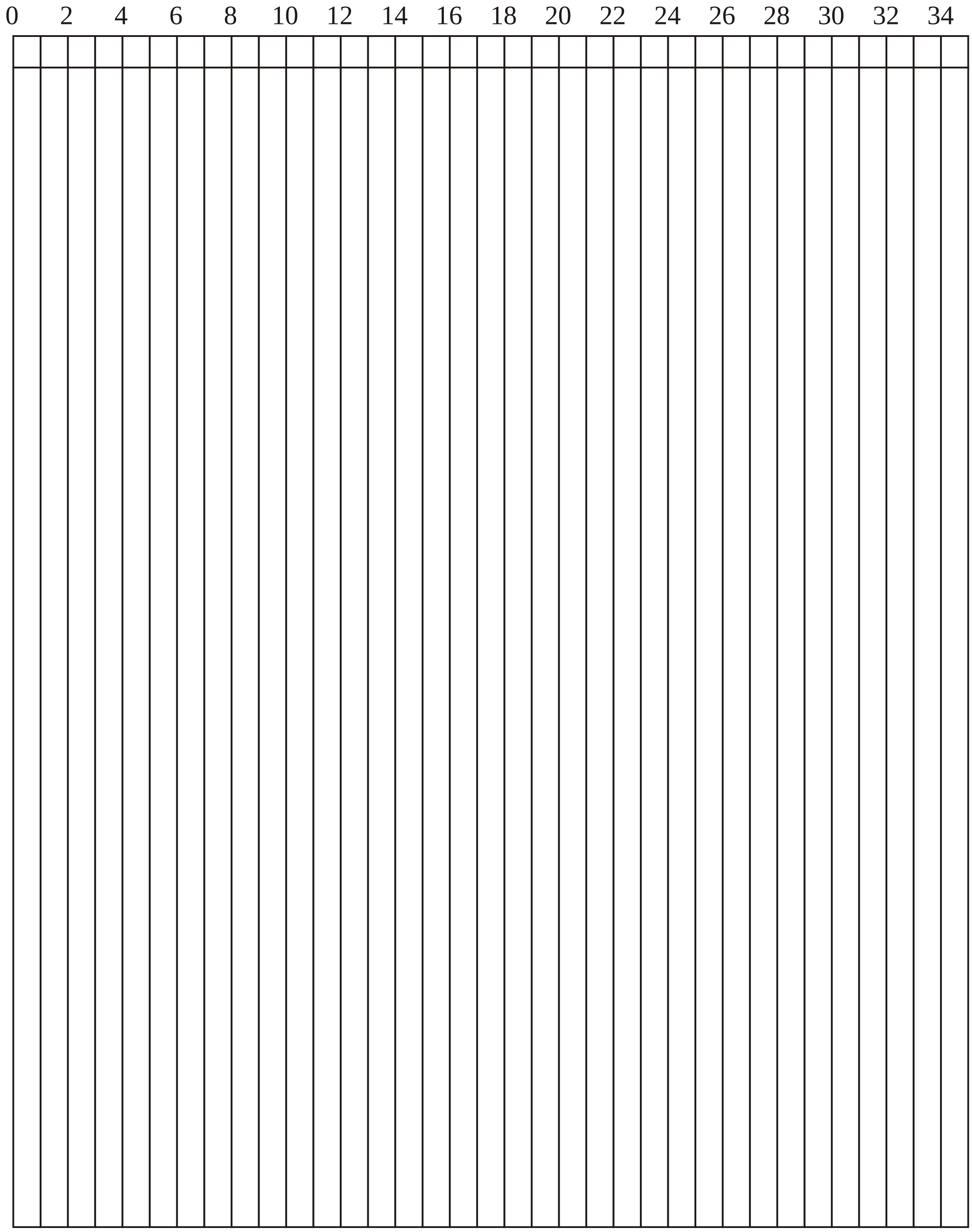
(b) List the critical activities.

(1)

(c) Calculate the total float on each of activities H and J.

(2)

(d) Draw a cascade (Gantt) chart for the project.



(4)

The engineer in charge of the project visits the site at midday on day 8 and sees that activity E has not yet been started.

(e) Determine if the project can still be completed on time. You must explain your answer.

(2)

Given that each activity requires one worker and that the project must be completed in 35 days,

(f) use your cascade chart to determine a lower bound for the number of workers needed. You must justify your answer.

(2)
(Total 14 marks)

6.

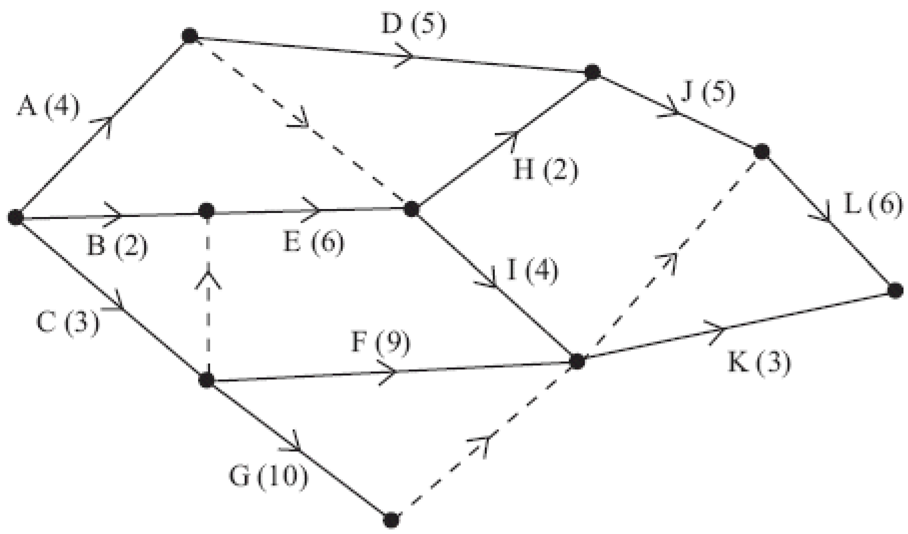


Figure 1

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

(a) Complete Figure 2 below to show the early and late event times.

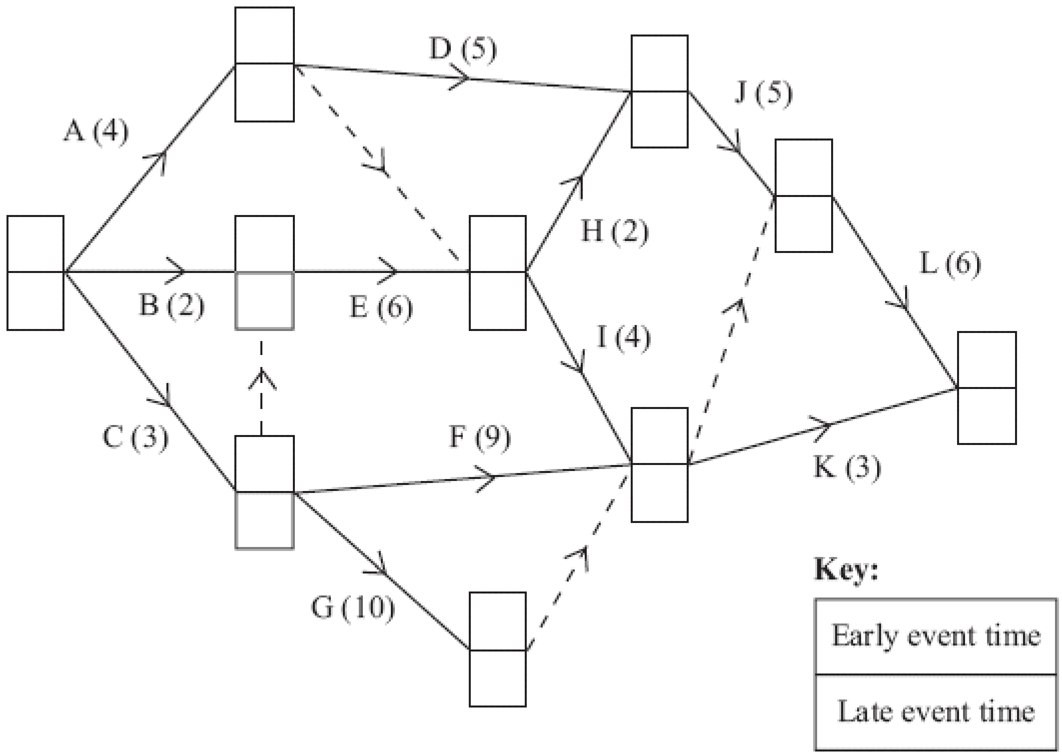


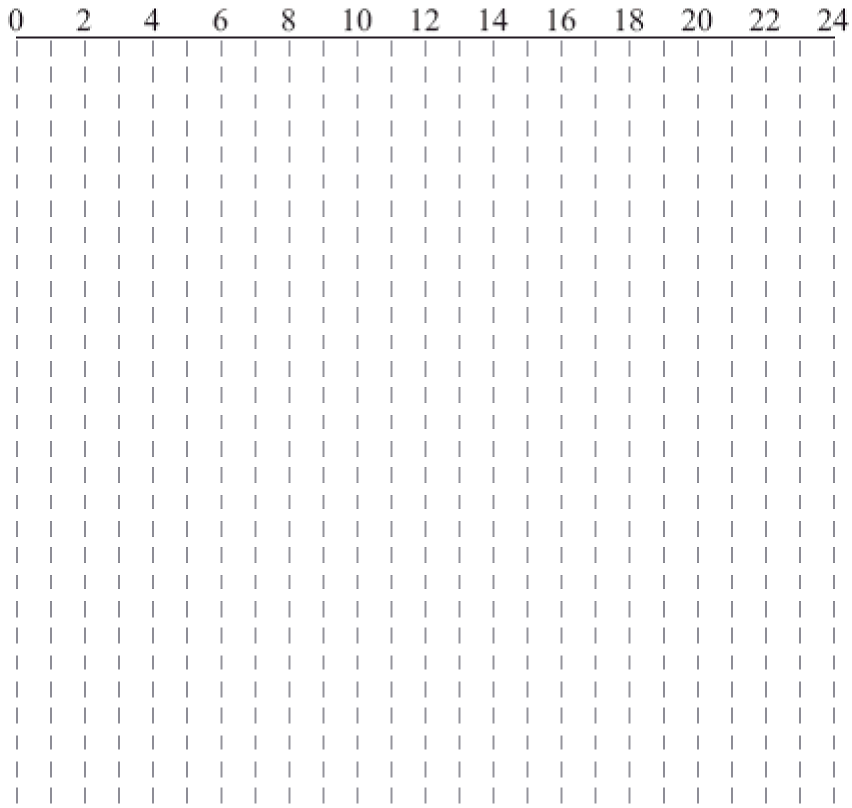
Figure 2

(4)

(b) State the critical activities.

(1)

(c) On the grid below, draw a cascade (Gantt) chart for this project.

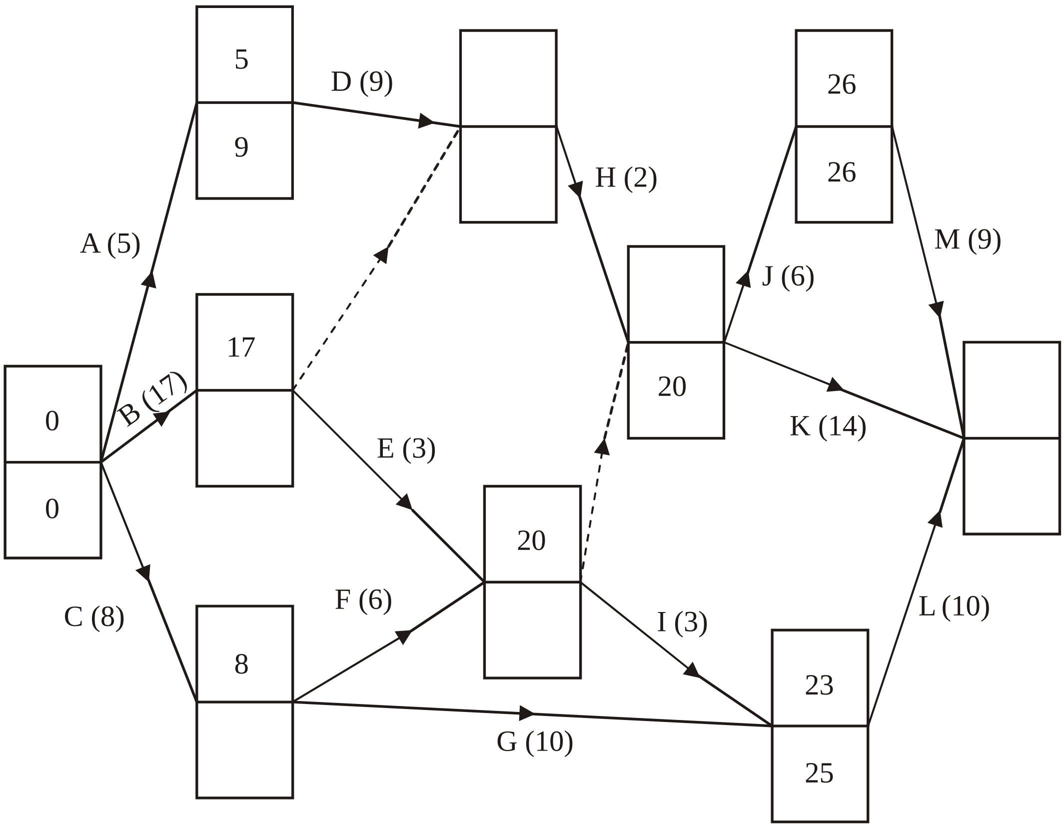


(4)

(d) Use your cascade chart to determine a lower bound for the number of workers needed.
You must justify your answer.

(2)
(Total 11 marks)

7.



A project is modelled by the activity network shown in the diagram above. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, to complete the activity. Some of the early and late times for each event are shown.

(a) Calculate the missing early and late times and hence complete the diagram above.

(4)

(b) Calculate the total float on activities D, G and I. You **must** make your calculations clear.

(4)

(c) List the critical activities.

(1)

Each activity requires one worker

(d) Calculate a lower bound for the number of workers needed to complete the project in the minimum time.

(2)
(Total 11 marks)

8. (a) Draw the activity network described in this precedence table, using activity on arc and exactly two dummies.

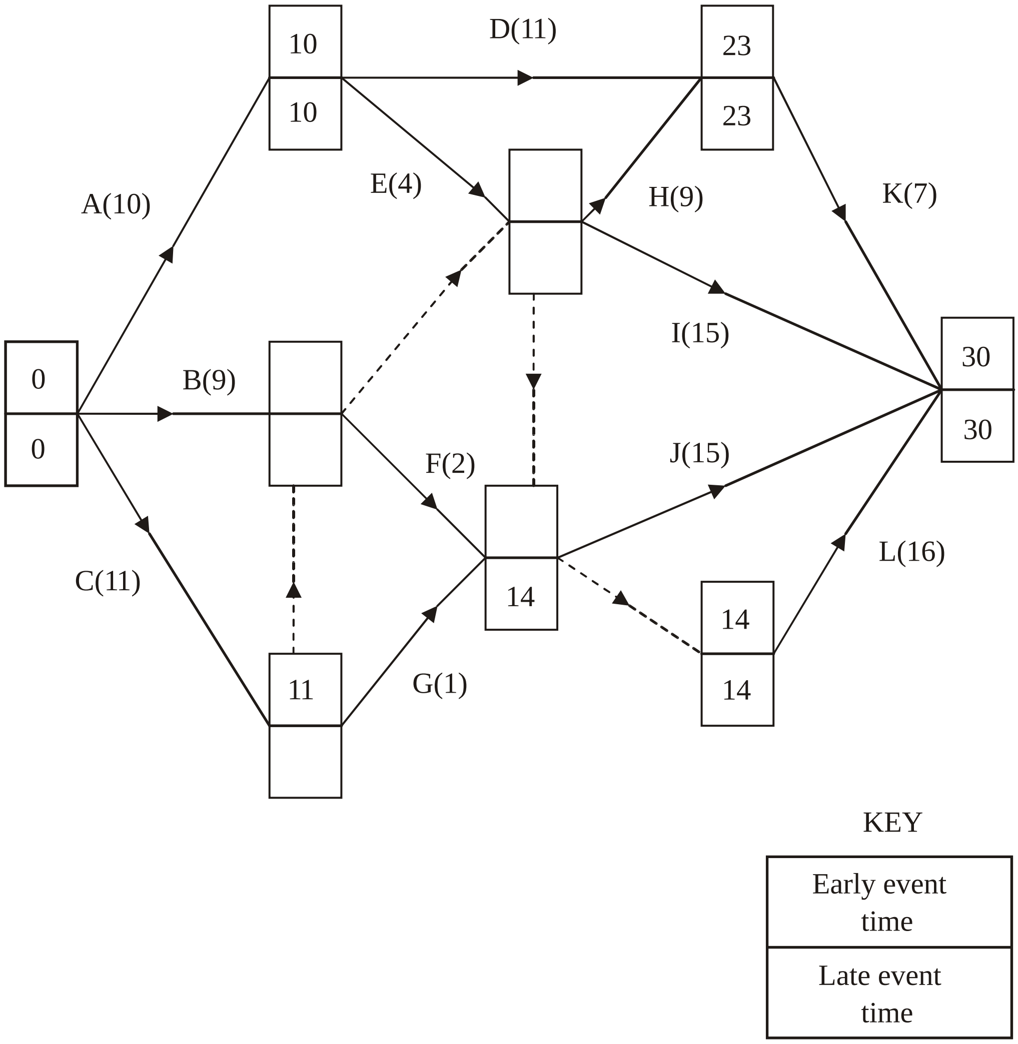
Activity	Immediately preceding activities
A	–
B	–
C	*A*
D	*B*
E	*B*, *C*
F	*B*, *C*

(4)

(b) Explain why each of the two dummies is necessary.

(3)
(Total 7 marks)

9.



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

(a) Calculate the missing early and late times and hence complete the diagram above.
(3)

(b) List the two critical paths for this network.
(2)

(c) Explain what is meant by a critical path.

(2)

The sum of all the activity times is 110 days and each activity requires just one worker. The project must be completed in the minimum time.

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

(2)

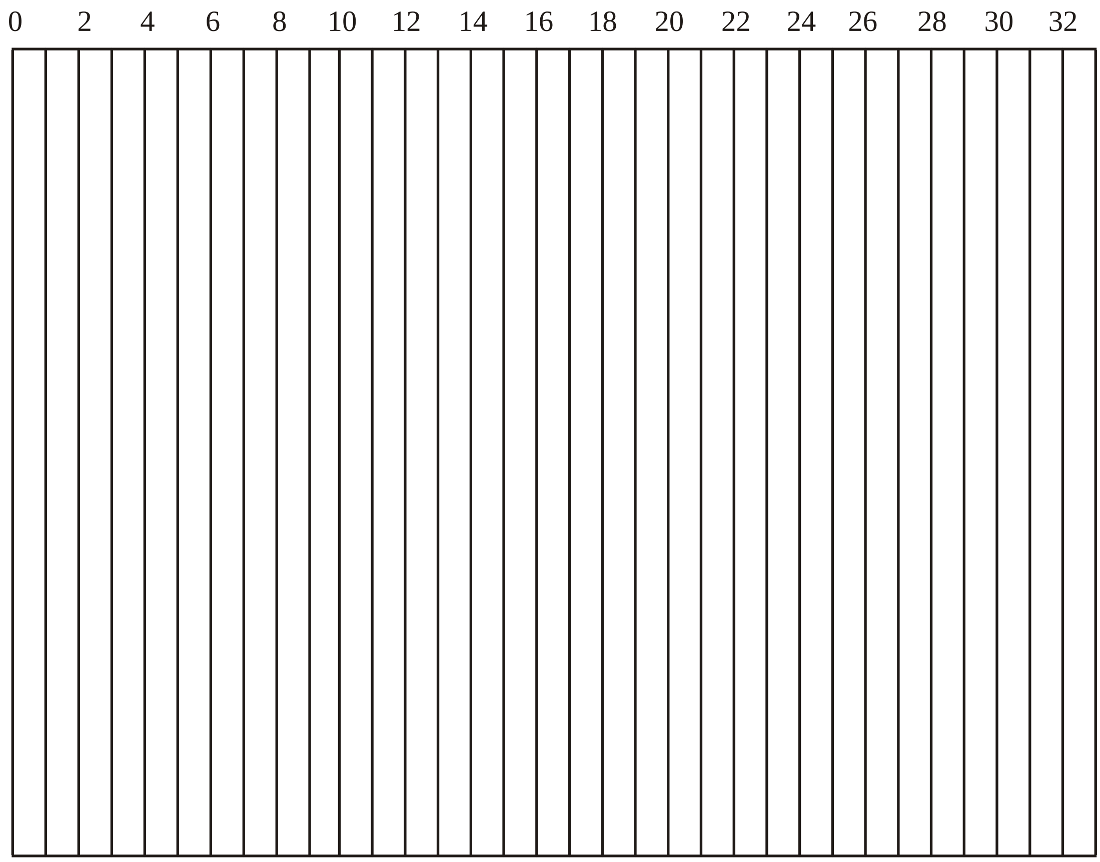
(e) List the activities that must be happening on day 20.

(2)

(f) Comment on your answer to part (e) with regard to the lower bound you found in part (d).

(1)

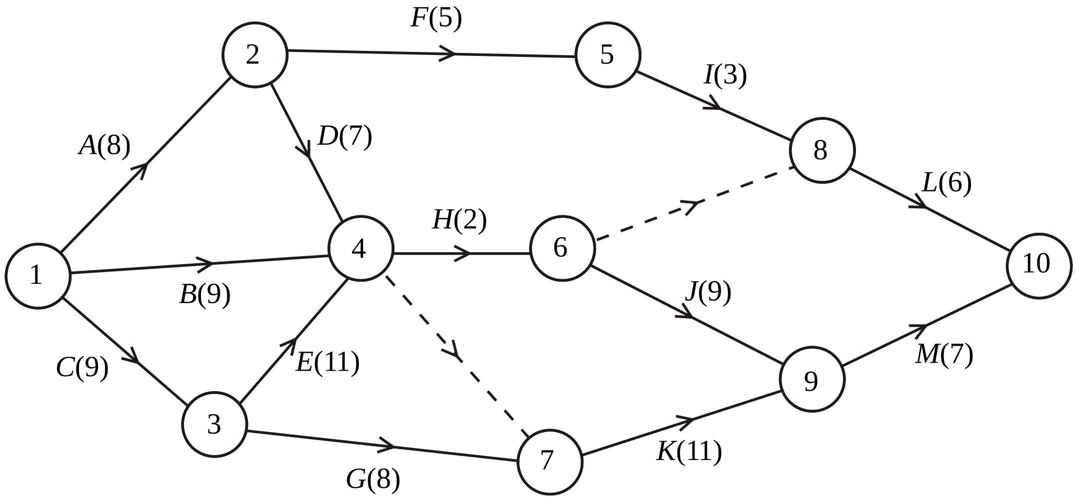
(g) Schedule the activities, using the minimum number of workers, so that the project is completed in 30 days.



(3)

(Total 15 marks)

10. **Figure 1**



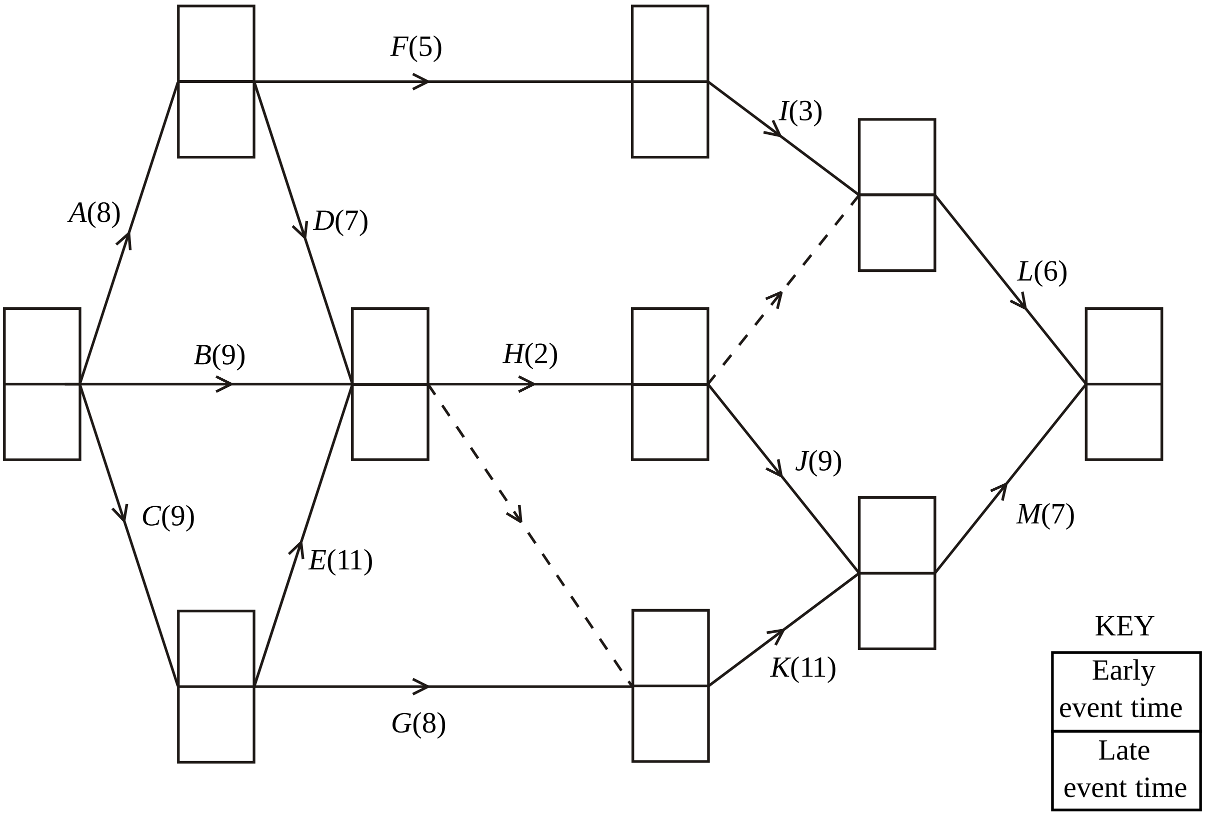
A project is modelled by the activity network shown in Figure 1. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, to complete the activity. The numbers in circles are the event numbers. Each activity requires one worker.

(a) Explain the purpose of the dotted line from event 6 to event 8.

(1)

(b) Calculate the early time and late time for each event. Write these in the boxes in Figure 2 below.

Figure 2



(4)

(c) Calculate the total float on activities *D*, *E* and *F*.

(3)

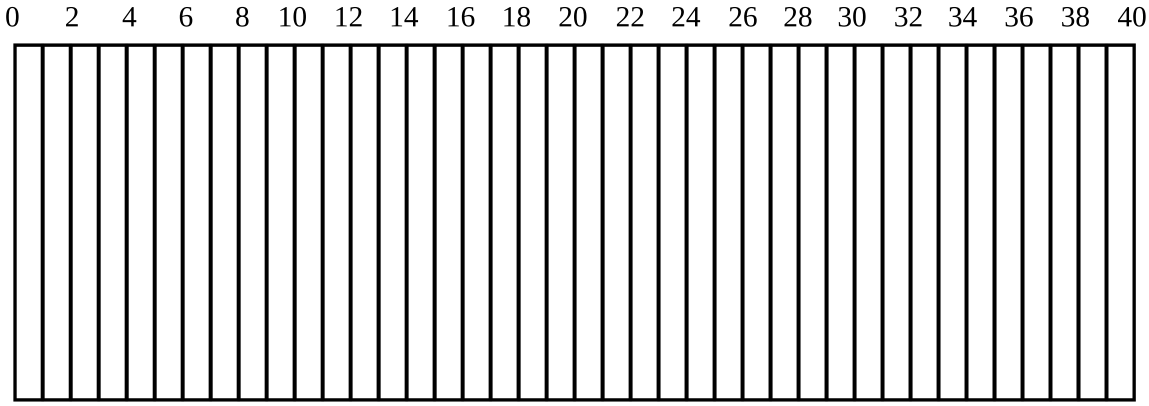
(d) Determine the critical activities.

(2)

(e) Given that the sum of all the times of the activities is 95 hours, calculate a lower bound for the number of workers needed to complete the project in the minimum time. You must show your working.

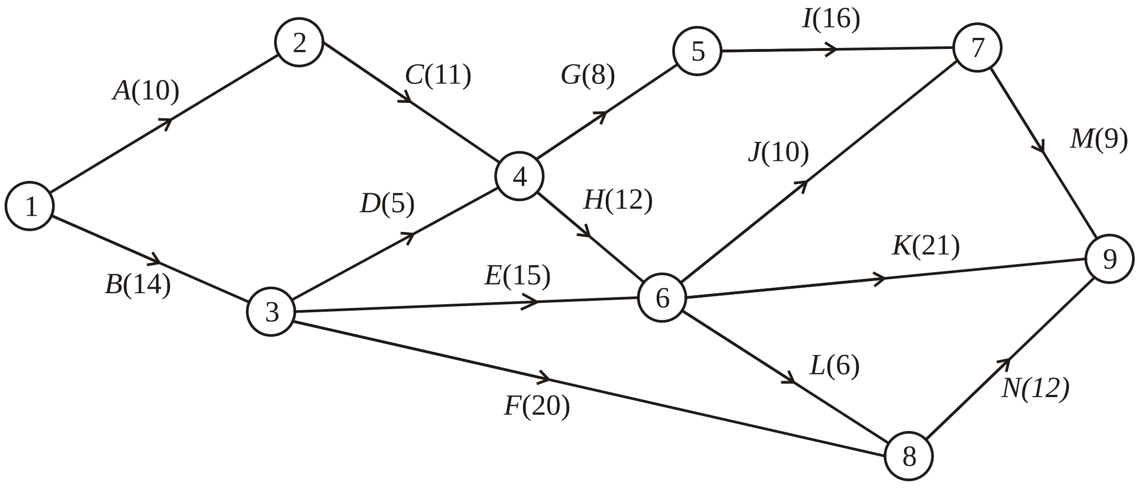
(2)

(f) Given that workers may not share an activity, schedule the activities so that the process is completed in the shortest time using the minimum number of workers.



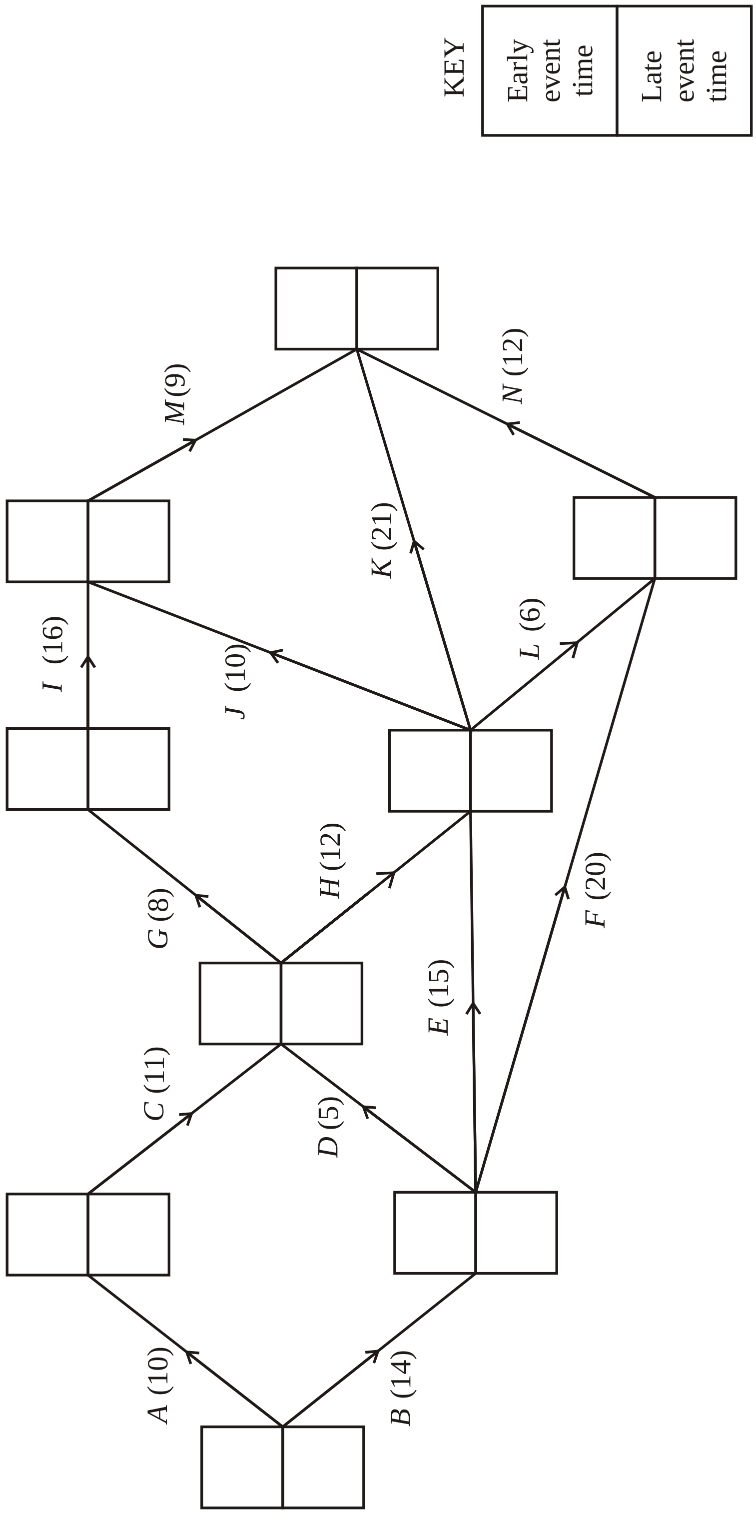
(4)
(Total 16 marks)

11.



An engineering project is modelled by the activity network shown in the figure above. The activities are represented by the arcs. The number in brackets on each arc gives the time, in days, to complete the activity. Each activity requires one worker. The project is to be completed in the shortest time.

(a) Calculate the early time and late time for each event. Write these in the boxes in the diagram below.



(4)

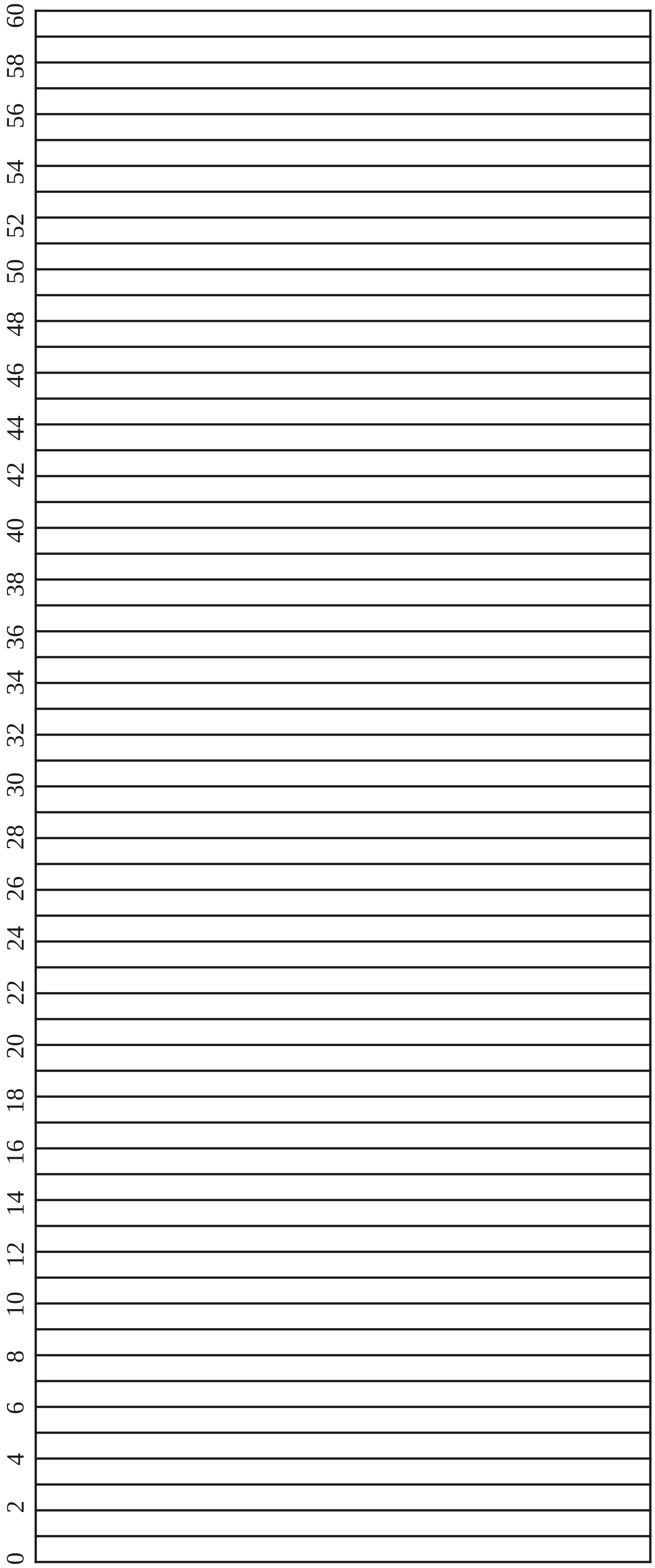
(b) State the critical activities.

(1)

(c) Find the total float on activities *D* and *F*. You must show your working.

(3)

(d) On the grid below, draw a cascade (Gantt) chart for this project.


0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60

(4)

The chief engineer visits the project on day 15 and day 25 to check the progress of the work. Given that the project is on schedule,

(e) which activities **must** be happening on each of these two days?

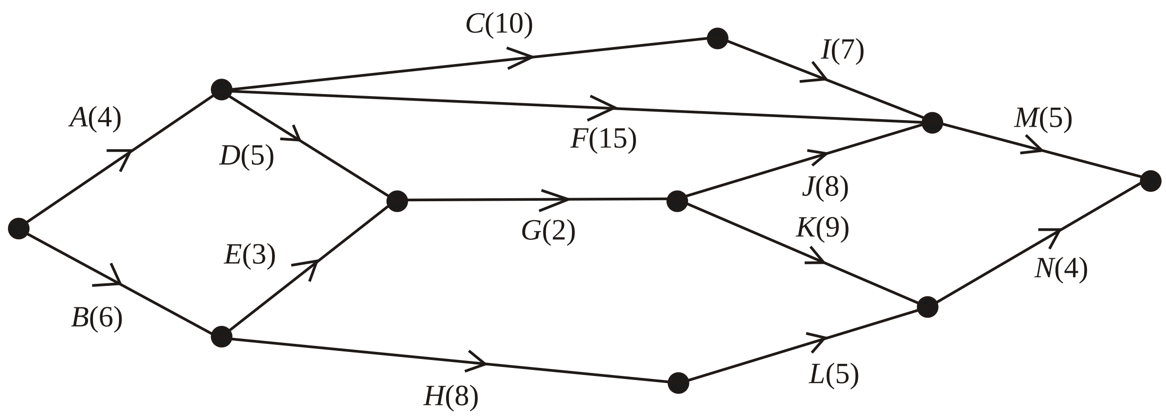
Activities that **must** be taking place on

(i) day 15..

(ii) day 25..

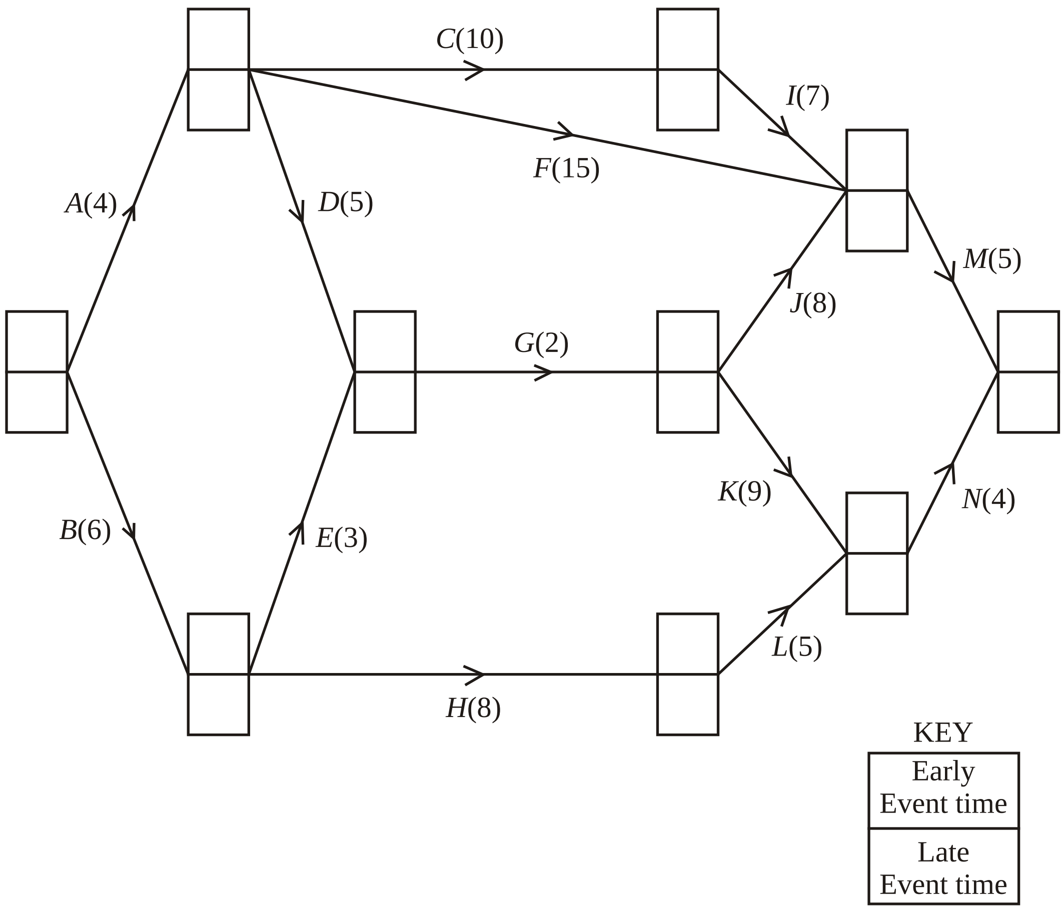
(3)
(Total 15 marks)

12.



The network in the figure above shows the activities involved in a process. The activities are represented by the arcs. The number in brackets on each arc gives the time, in days, taken to complete the activity.

(a) Calculate the early time and late time for each event, showing them on the diagram below.



(4)

(b) Determine the critical activities and the length of the critical path.

Critical activities ....

Length of critical path ....

(2)

(c) On the grid below, draw a cascade (Gantt) chart for the process.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

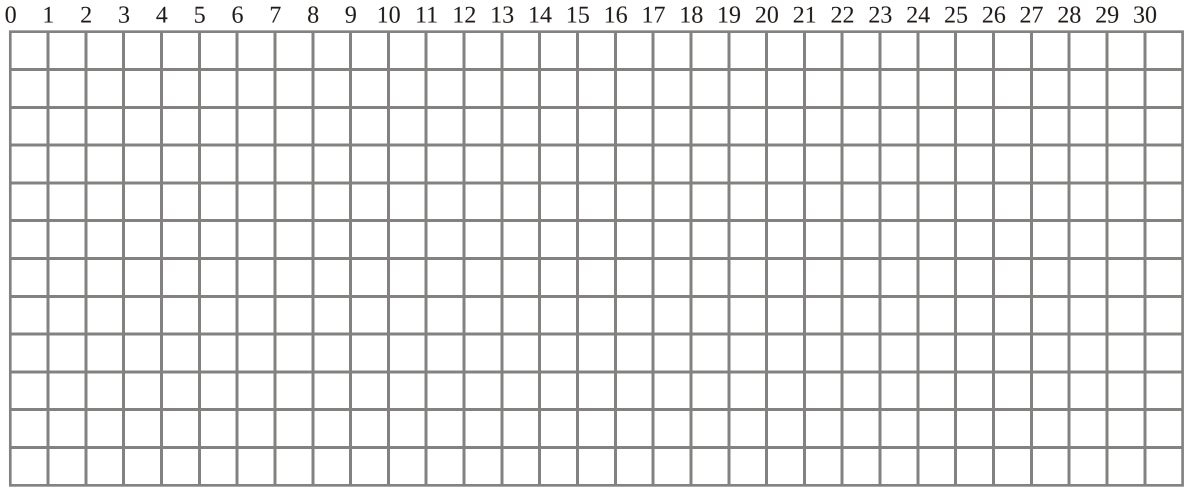
(4)

Each activity requires only one worker, and workers may not share an activity.

(d) Use your cascade chart to determine the minimum numbers of workers required to complete the process in the minimum time. Explain your reasoning clearly.

(2)

(e) Schedule the activities, using the number of workers you found in part (d), so that the process is completed in the shortest time.



(3)
(Total 15 marks)

13. The precedence table shows the activities involved in a project.

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

(a) Draw the activity network for this project, using activity on arc and using two dummies.

(4)

(b) Explain why each of the two dummies is necessary.

(3)
(Total 7 marks)

14. The precedence table for activities involved in producing a computer game is shown below.

Activity	Must be preceded by
A	–
B	–
C	*B*
D	*A*, *C*
E	*A*
F	*E*
G	*E*
H	*G*
I	*D*, *F*
J	*G*, *I*
K	*G*, *I*
L	*H*, *K*

An activity on arc network is to be drawn to model this production process.

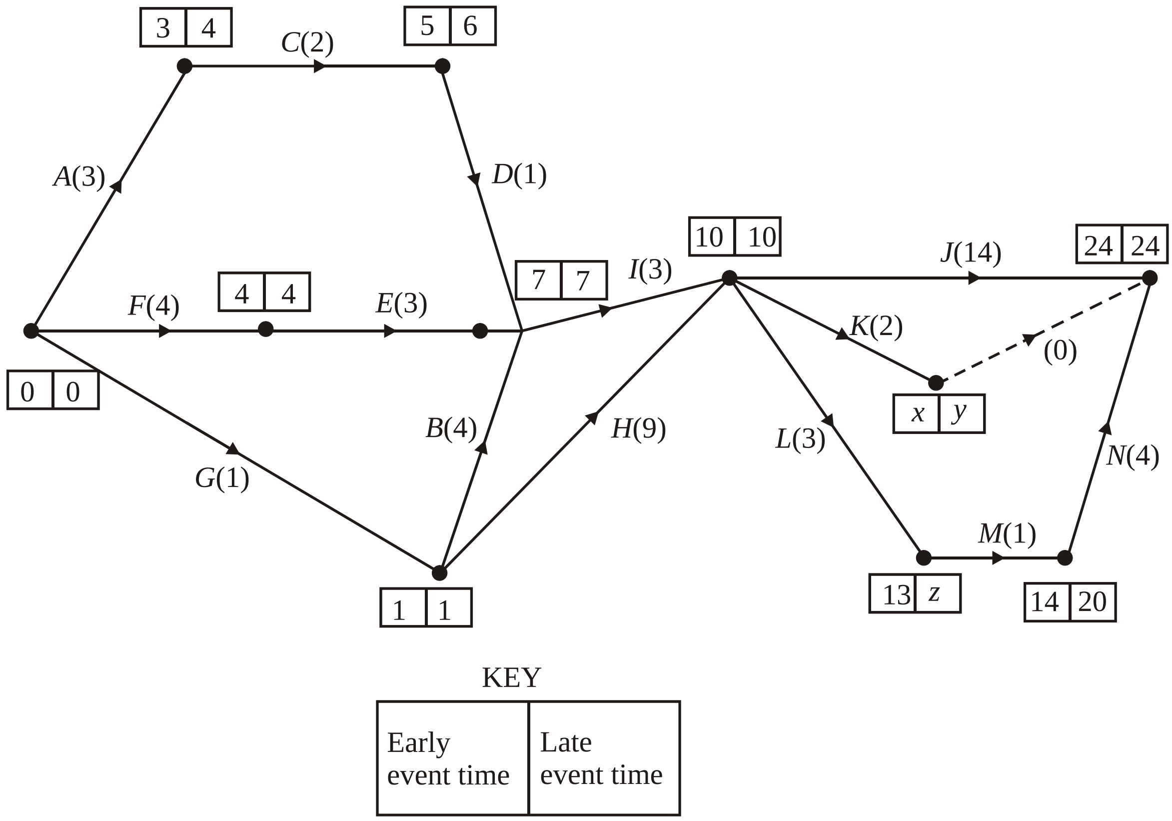
(a) Explain why it is necessary to use at least two dummies when drawing the activity network.

(2)

(b) Draw the activity network using exactly two dummies.

(5)
(Total 7 marks)

15.



The network in the diagram above shows activities that need to be undertaken in order to complete a project. Each activity is represented by an arc. The number in brackets is the duration of the activity in hours. The early and late event times are shown at each node. The project can be completed in 24 hours.

(a) Find the values of x, y and z.

(3)

(b) Explain the use of the dummy activity in the diagram above.

(1)

(c) List the critical activities.

(2)

(d) Explain what effect a delay of one hour to activity *B* would have on the time taken to complete the whole project.

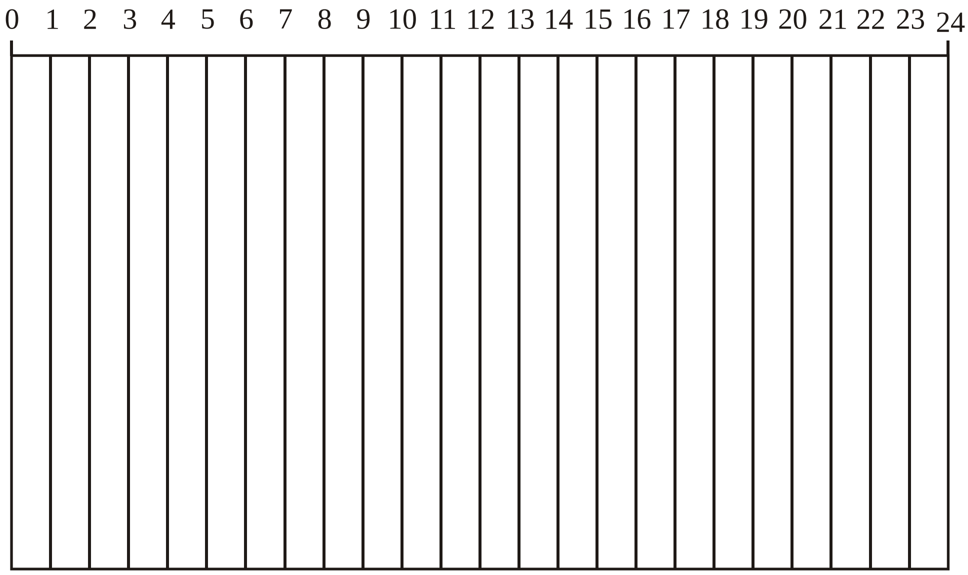
(2)

The company which is to undertake this project has only two full time workers available. The project must be completed in 24 hours and in order to achieve this, the company is prepared to hire additional workers at a cost of £28 per hour. The company wishes to minimise the money spent on additional workers. Any worker can undertake any task and each task requires only one worker.

(e) Explain why the company will have to hire additional workers in order to complete the project in 24 hours.

(2)

(f) Schedule the tasks to workers so that the project is completed in 24 hours and at minimum cost to the company.

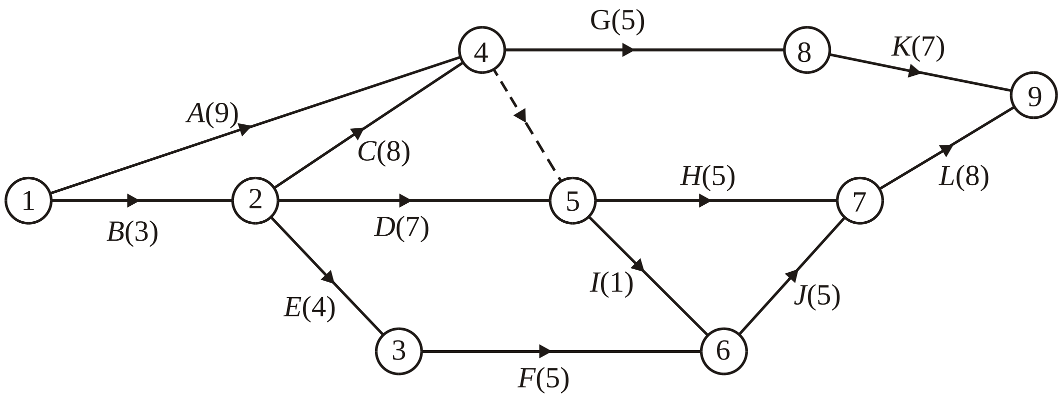


(5)

(g) State the minimum extra cost to the company.

(2)
(Total 17 marks)

16.

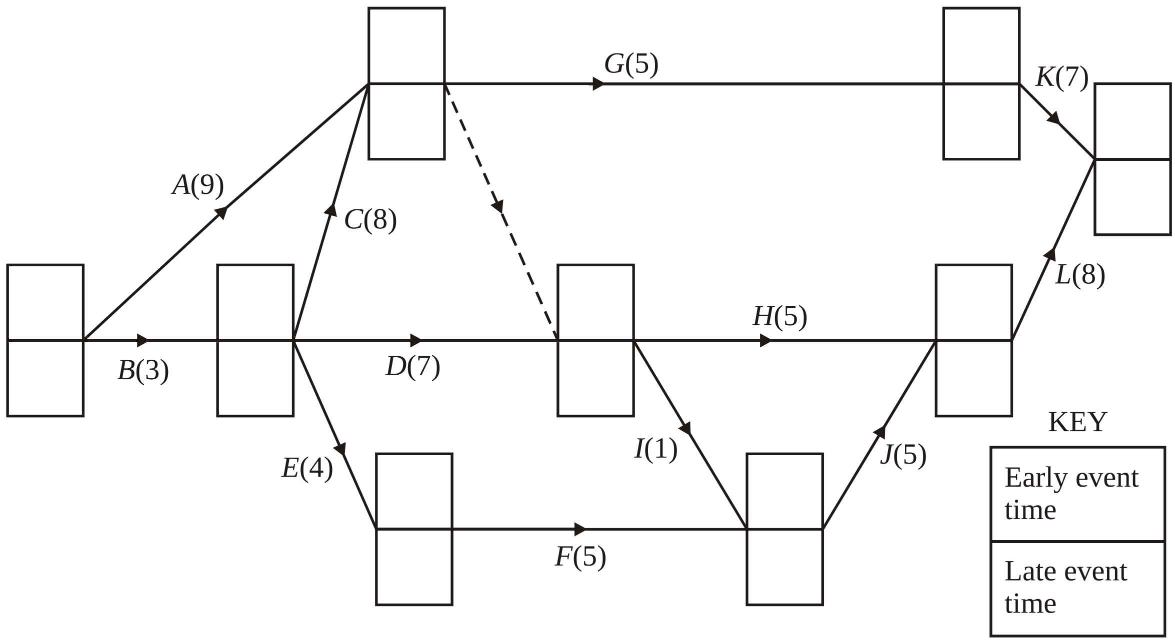


A project is modelled by the activity network shown in the diagram above. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, to complete the activity. The numbers in circles give the event numbers. Each activity requires one worker.

(a) Explain the purpose of the dotted line from event 4 to event 5.

(1)

(b) Calculate the early time and the late time for each event. Write these in the boxes in the diagram below.



(4)

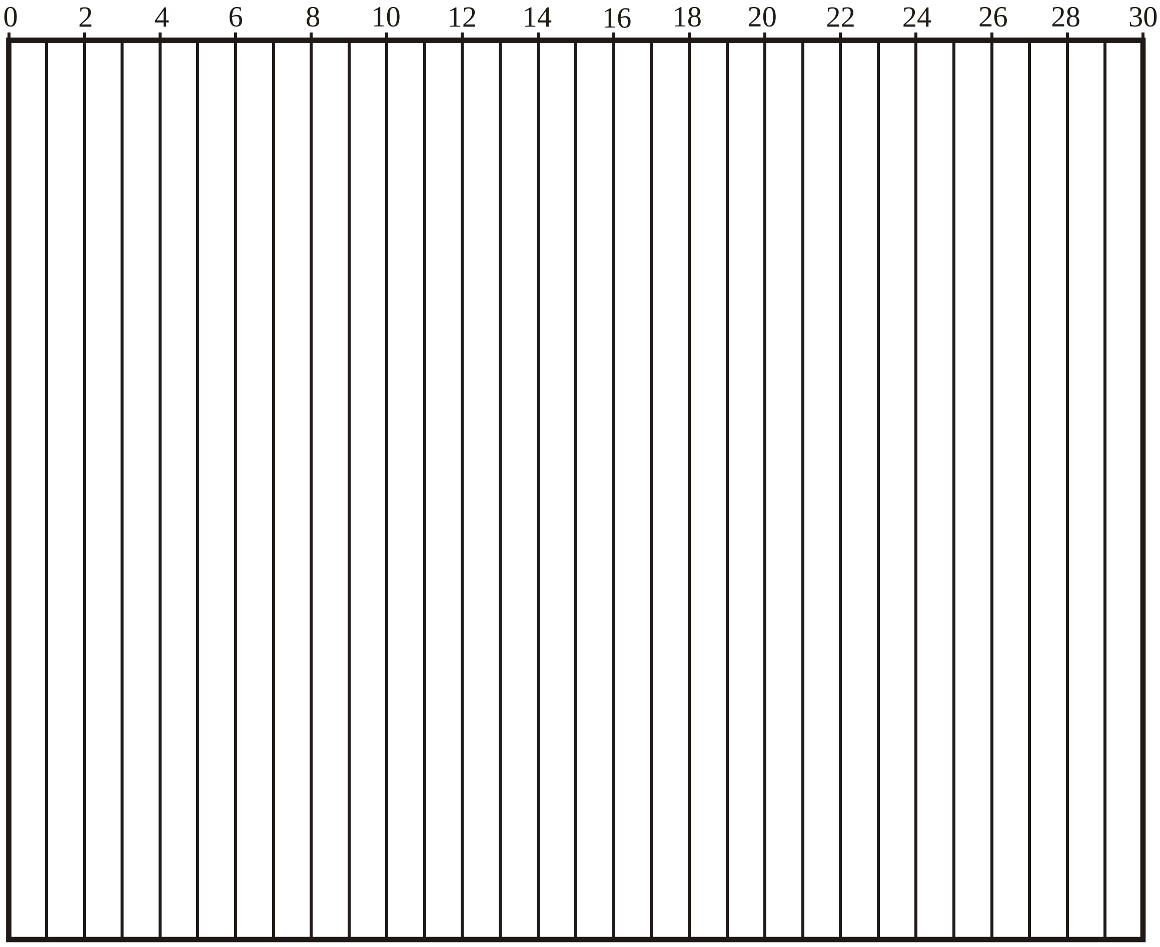
(c) Determine the critical activities.

(1)

(d) Obtain the total float for each of the non-critical activities.

(3)

(e) On the grid below, draw a cascade (Gantt) chart, showing the answers to parts (c) and (d).

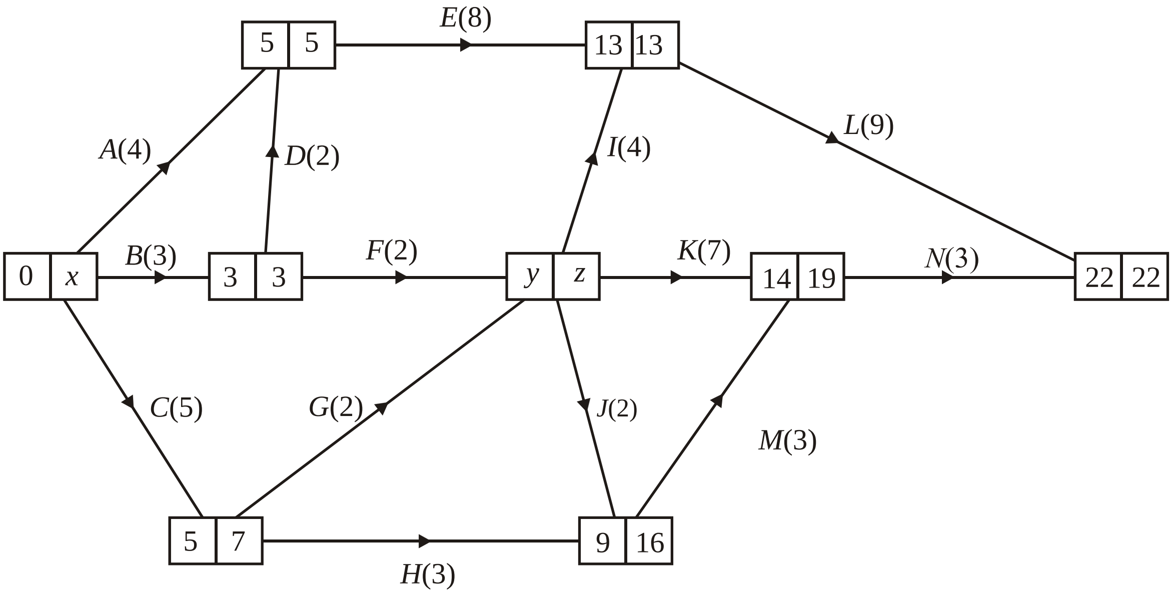


(4)

(f) Determine the minimum number of workers needed to complete the project in the minimum time. Make your reasoning clear.

(2)
(Total 15 marks)

17.



A trainee at a building company is using critical path analysis to help plan a project. The diagram above shows the trainee's activity network. Each activity is represented by an arc and the number in brackets on each arc is the duration of the activity, in hours.

(a) Find the values of x, y and z.

(3)

(b) State the total length of the project and list the critical activities.

(2)

(c) Calculate the total float time on

(i) activity N,

(ii) activity H.

(3)

The trainee's activity network is checked by the supervisor who finds a number of errors and omissions in the diagram. The project should be represented by the following precedence table.

Activity	Must be preceded by:	Duration
A	–	4
B	–	3
C	–	5
D	*B*	2
E	*A*, *D*	8
F	*B*	2
G	*C*	2
H	*C*	3
I	*F*, *G*	4
J	*F*, *G*	2
K	*F*, *G*	7
L	*E*, *I*	9
M	*H*, *J*	3
N	*E*, *I*, *K*, *M*	3
P	*E*, *I*	6
Q	*H*, *J*	5
R	*Q*	7

(d) By adding activities and dummies amend the diagram above so that it represents the precedence table. (The **durations** of activities *A*, *B*, ..., *N* are all correctly given on the diagram.)

(4)

(e) Find the total time needed to complete this project.

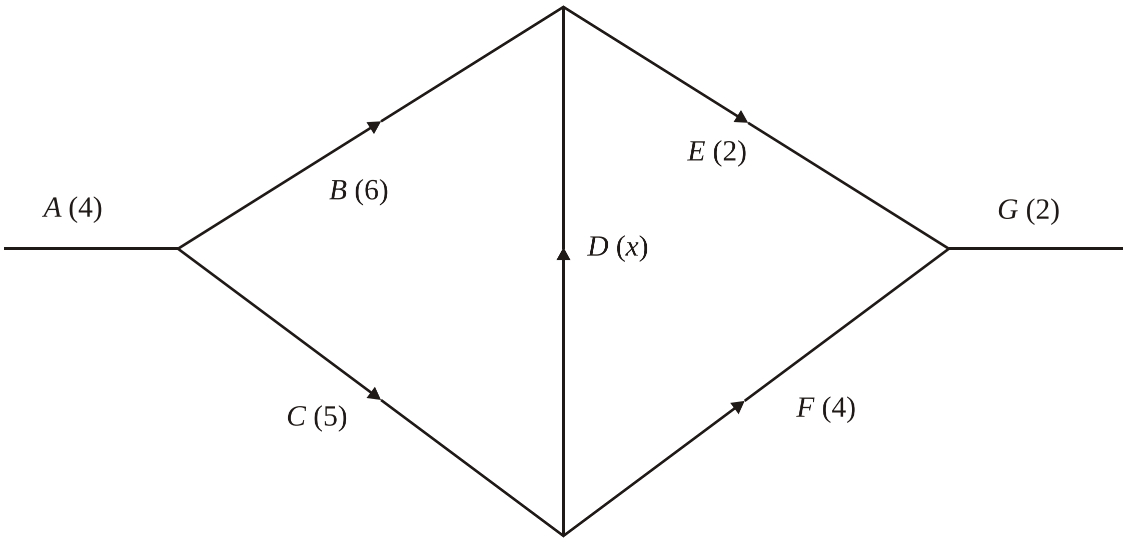
(2)
(Total 14 marks)

18. (a) Draw an activity network described in this precedence table, using as few dummies as possible.

Activity	Must be preceded by:
A	–
B	*A*
C	*A*
D	*A*
E	*C*
F	*C*
G	*B*, *D*, *E*, *F*
H	*B*, *D*, *E*, *F*
I	*F*, *D*
J	*G*, *H*, *I*
K	*F*, *D*
L	*K*

(b) A **different** project is represented by the activity network shown in Fig. 3. The duration of each activity is shown in brackets.

Figure 3

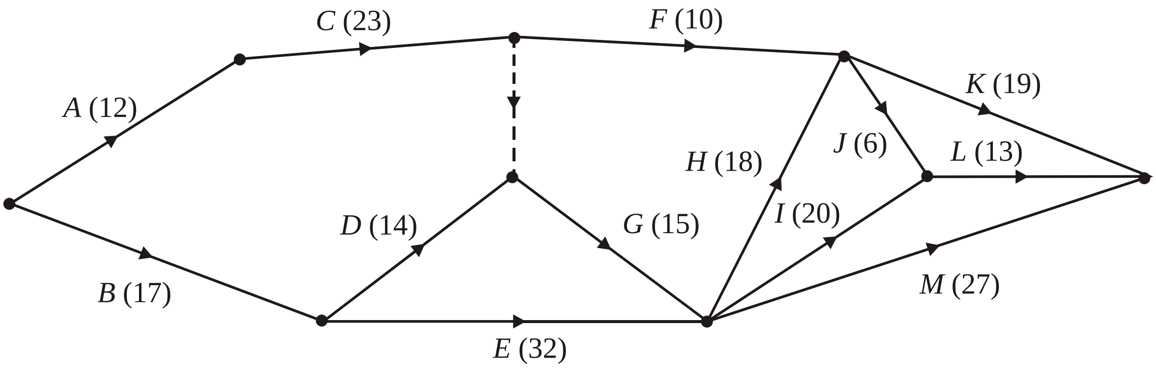


Find the range of values of x that will make D a critical activity.

(Total 2 marks)

19.

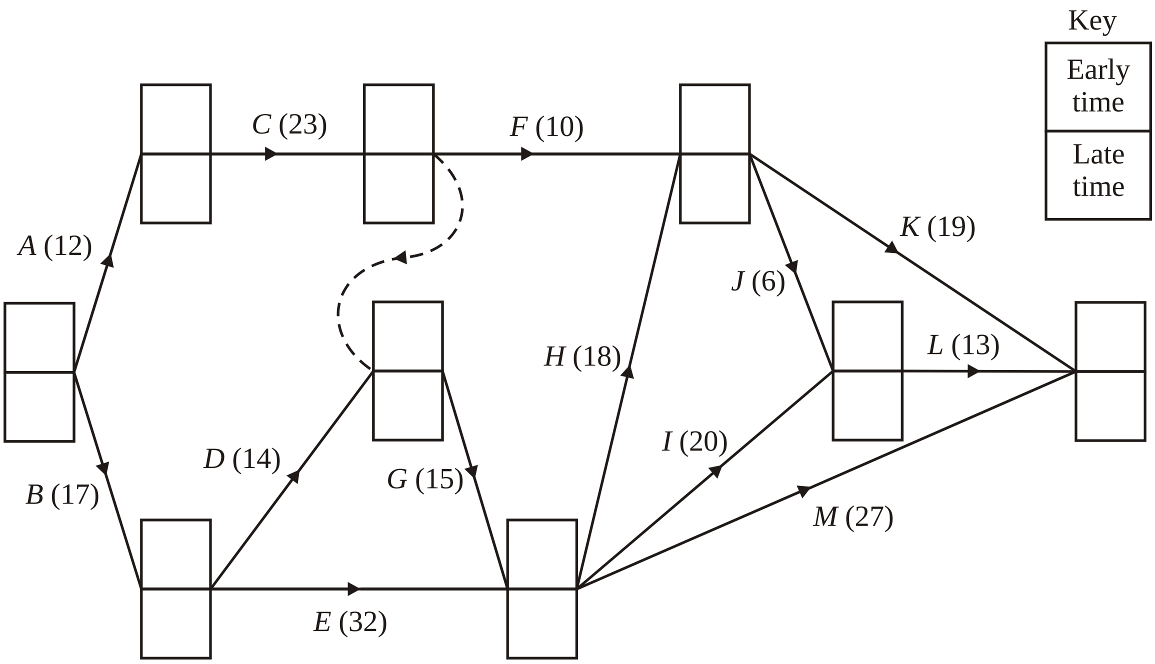
Figure 1



The network in Fig. 1 shows the activities involved in the process of producing a perfume. The activities are represented by the arcs. The number in brackets on each arc gives the time, in hours, taken to complete the activity.

(a) Calculate the early time and the late time for each event, showing them on Diagram 1 below.

Diagram 1



(4)

(b) Hence determine the critical activities.

(2)

(c) Calculate the total float time for *D*.

(2)

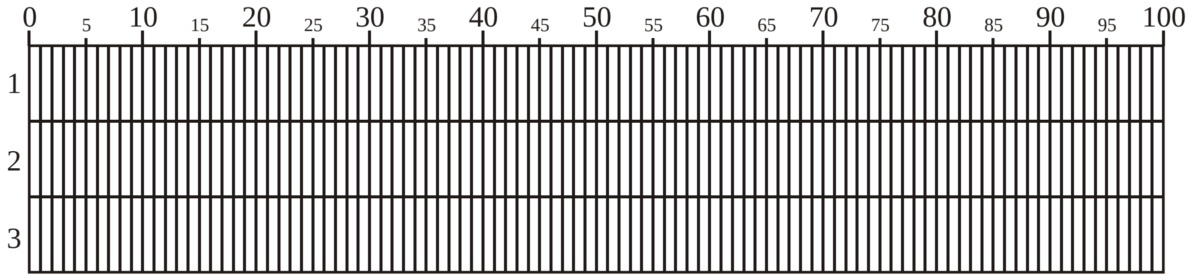
Each activity requires only one person.

(d) Find a lower bound for the number of workers needed to complete the process in the minimum time.

(2)

Given that there are only three workers available, and that workers may **not** share an activity,

(e) schedule the activities so that the process is completed in the shortest time. Use the time line below. State the new shortest time.



1 ....

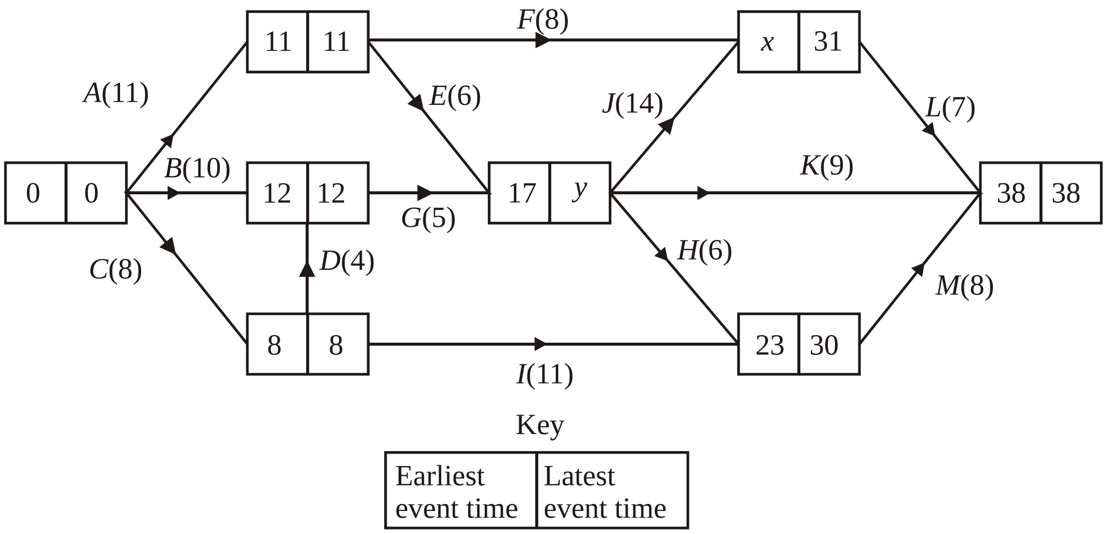
2 ....

3 ....

New shortest time ....

(5)
(Total 15 marks)

20.



A project is modelled by the activity network in the diagram above. The activities are represented by the arcs. One worker is required for each activity. The number in brackets on each arc gives the time, in hours, to complete the activity. The earliest event time and the latest event time are given by the numbers in the left box and right box respectively.

(a) State the value of *x* and the value of *y*.

(2)

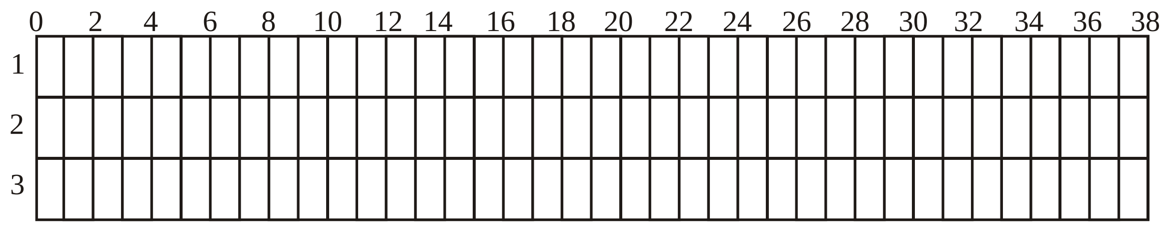
(b) List the critical activities.

(2)

(c) Explain why at least 3 workers will be needed to complete this project in 38 hours.

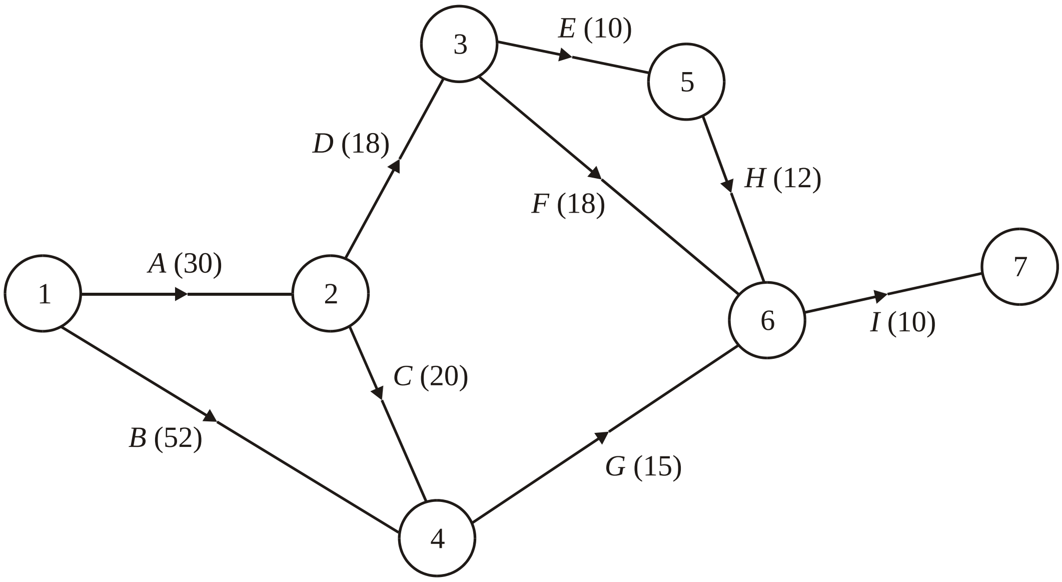
(2)

(d) Schedule the activities so that the project is completed in 38 hours using just 3 workers. You must make clear the start time and finish time of each activity.



(4)
(Total 10 marks)

21. *This question should be answered on the pages below.*



A building project is modelled by the activity network shown in the diagram above. The activities involved in the project are represented by the arcs. The numbers in brackets on each arc gives the time, in days, taken to complete the activity.

(a) Complete the boxes on the answer sheet by calculating the earliest and latest event times. **(4)**

(b) Hence write down the critical activities and the length of the critical path. **(2)**

(c) Obtain the total float for each non-critical activity. **(2)**

(d) On the grid on the answer sheet, draw a cascade (Gantt) chart showing the information found in parts (*b*) and (*c*). **(3)**

Given that each activity requires one worker,

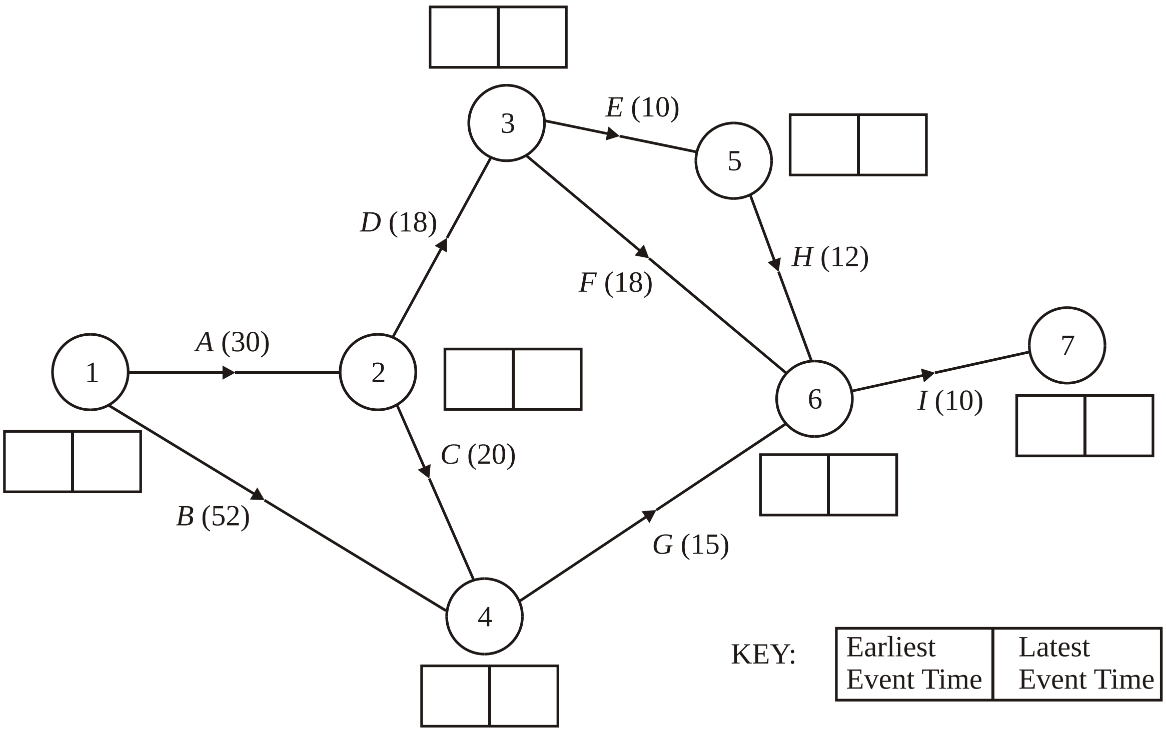
(e) draw up a schedule to determine the minimum number of workers needed to complete the project in the critical time. **(3)**

Due to unforeseen circumstances, activity *C* takes 30 days rather than 20 days.

(f) Determine how this affects the length of the critical path and state the critical activities now.

(3)
(Total 17 marks)

Sheet for use in answering this question



(b) Length of critical path: ………………………………………………………………

Critical activities: ……………………………………………………………………

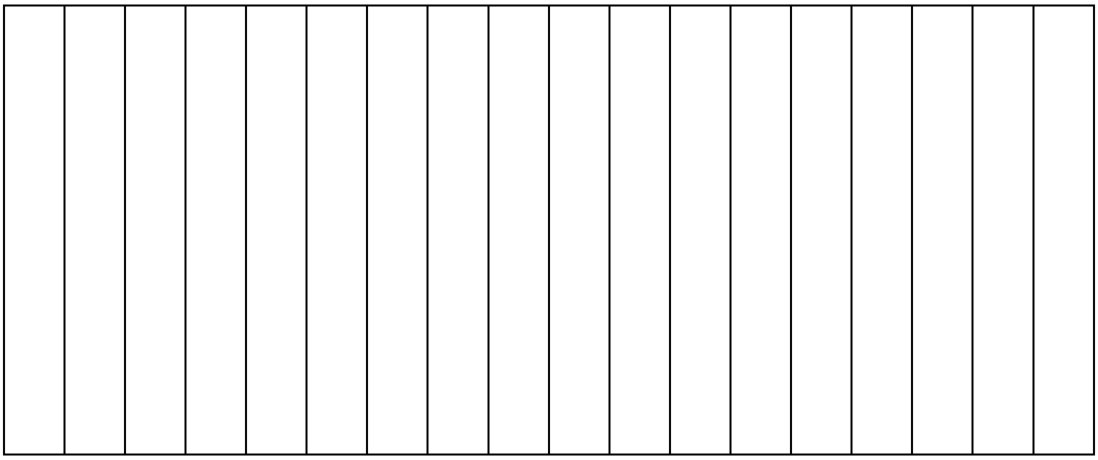
(c) Floats on critical activities:…………………………………………………………..

...……………………………………………………………………………………...........

...……………………………………………………………………………………...........

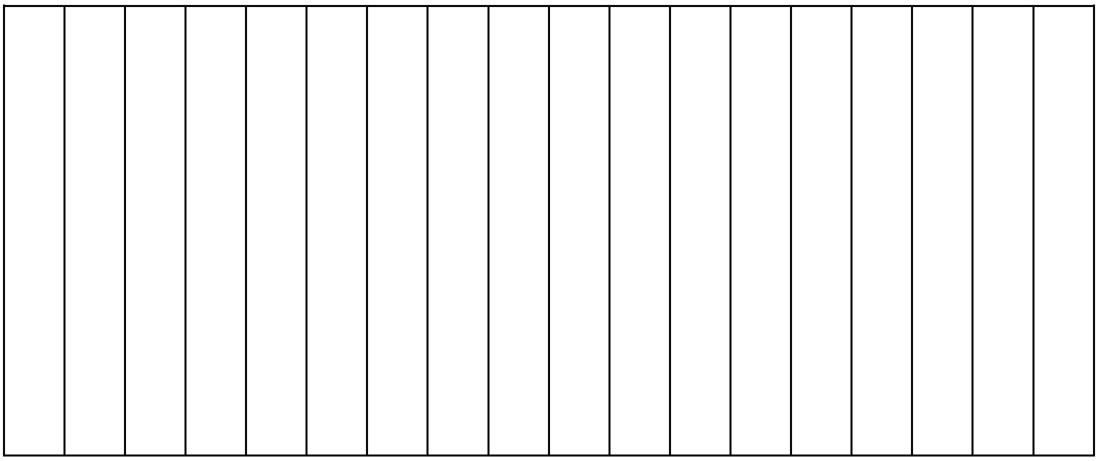
(d)

0 5 10 15 20 25 30 35 40 45 50 55 60 65
70 75 80 85 90



(e)

0 5 10 15 20 25 30 35 40 45 50 55 60 65
70 75 80 85 90



(f)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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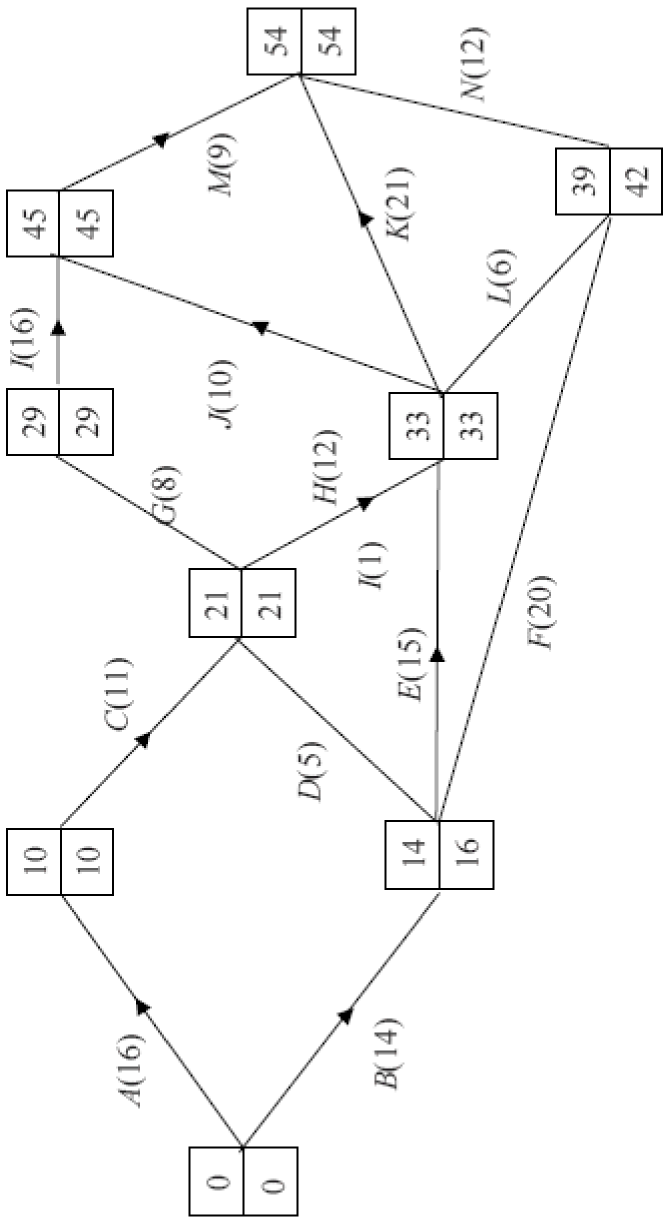
1. (a)



M1A1 2

M1A1 2

(b)

$G - I - M$

A $H - K$

C

A1 1

(c) Float on $D = 21 - 5 - 14 = 2$ B1ft

Float on $F = 42 - 20 - 14 = 8$ M1A1 ft 3

(d)	Gantt Chart		B4	4
(e)	Day 15:	*C*	B1	
	Day 25:	*G, H, E, F*	B2,1,0	3

[15]

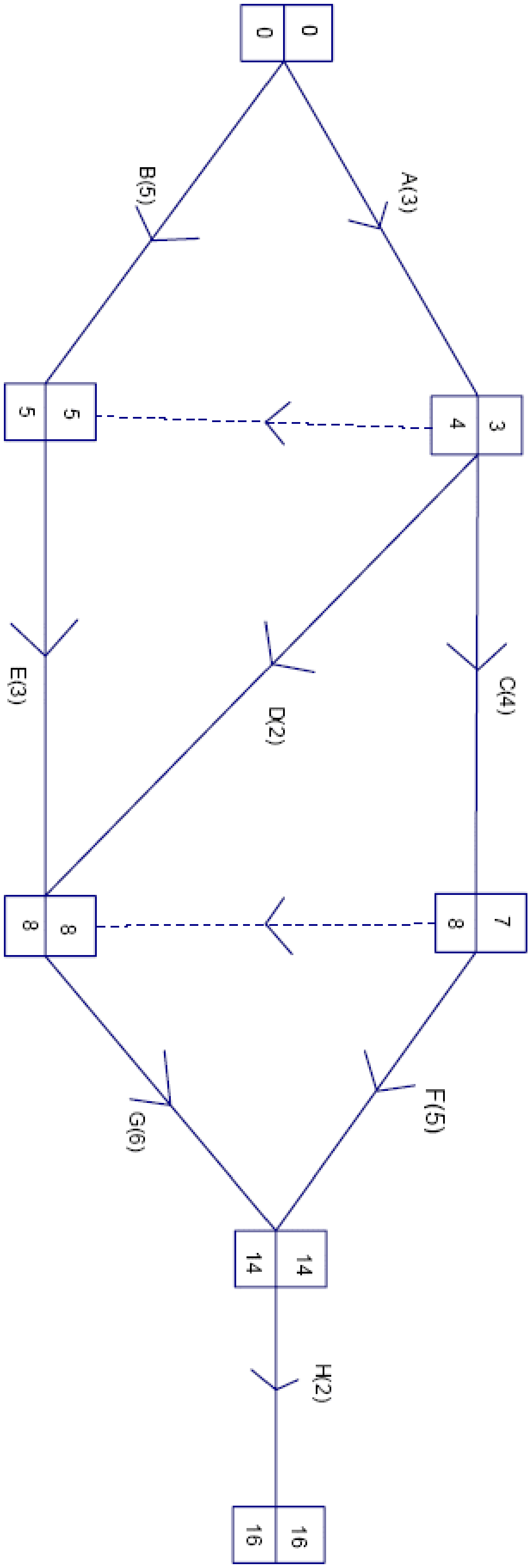
2. (a) The dotted line represents a dummy activity. B1

It is necessary because C and D depend only on A, but E depends on A and B. B1 2

(b)

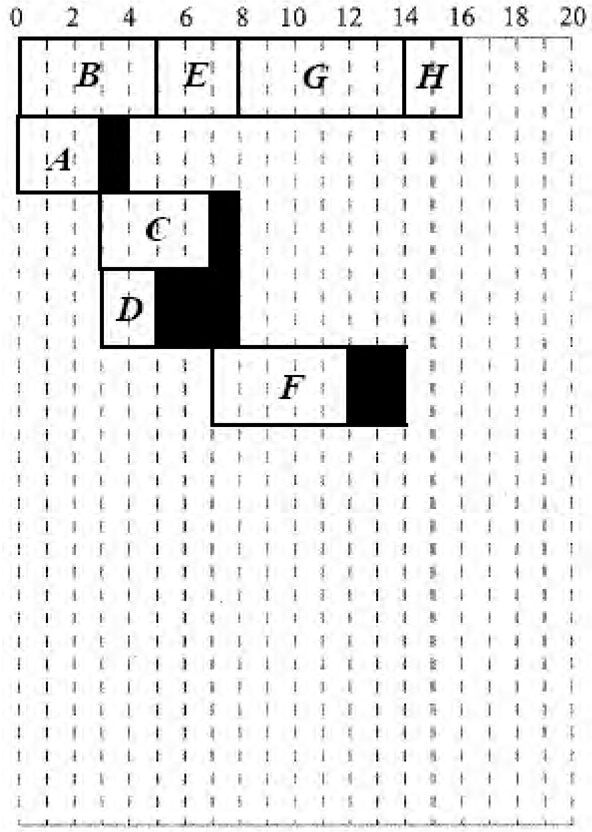
Activity	Immediately preceding activity			
A	-			
B	-			
C	A	To this point	B1	
D	A			
E	A,B			
F	C (A)	For E & F, accepting correct “extra”	B1	
G	C, D, E			
H	F, G	Last two rows, correct only,	B1	3

(c)


A(3)
B(5)
C(4)
D(2)
E(3)
F(5)
G(6)
H(2)
0 0
3 4
5 5
7 8
8 8
14 14
16 16

	Early times	M1A1	
	Late times	M1A1	4
(d)	Critical activities: B, E, G, H	B1	
	Critical path: 16 days	B1ft	2

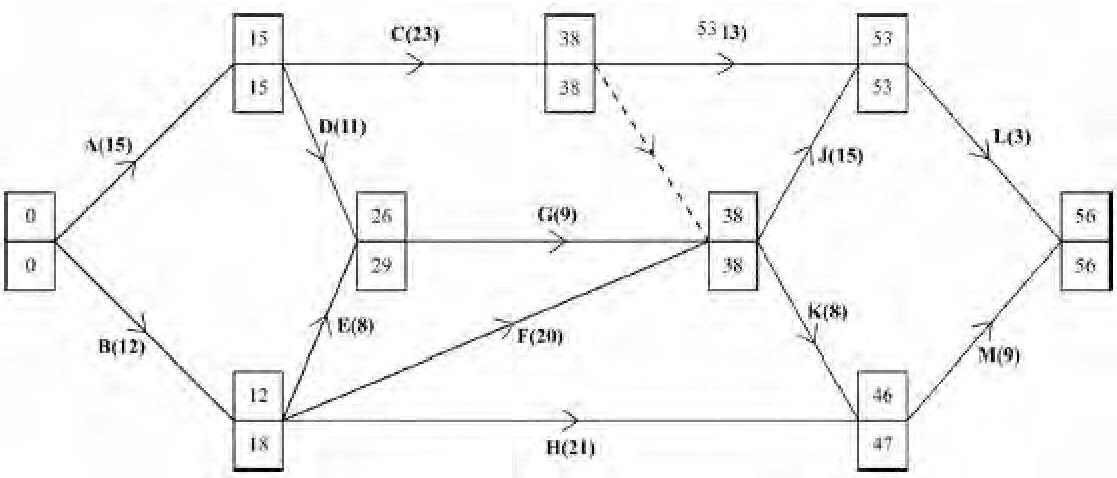
(e)



At least 6 activities placed including at least 3 floats	M1	
Critical Activities	A1	
A + C	A1	
D + F	A1	4

[15]

3. (a)



M1 A1

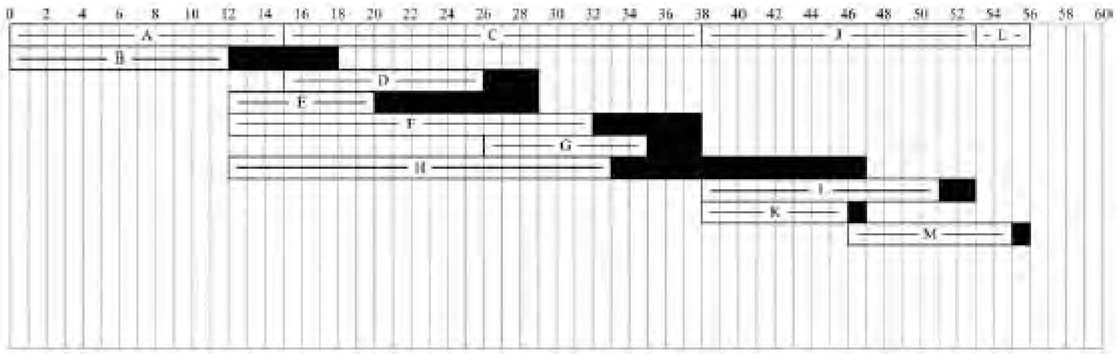
M1 A1 4

(b) A C J L B1 1

(c) Total float for M = 56(ft) – 46 – 9 = 1 M1 A1ft

Total float for H = 47 – 12 – 21 = 14 B1 3

(d)



M1 A1

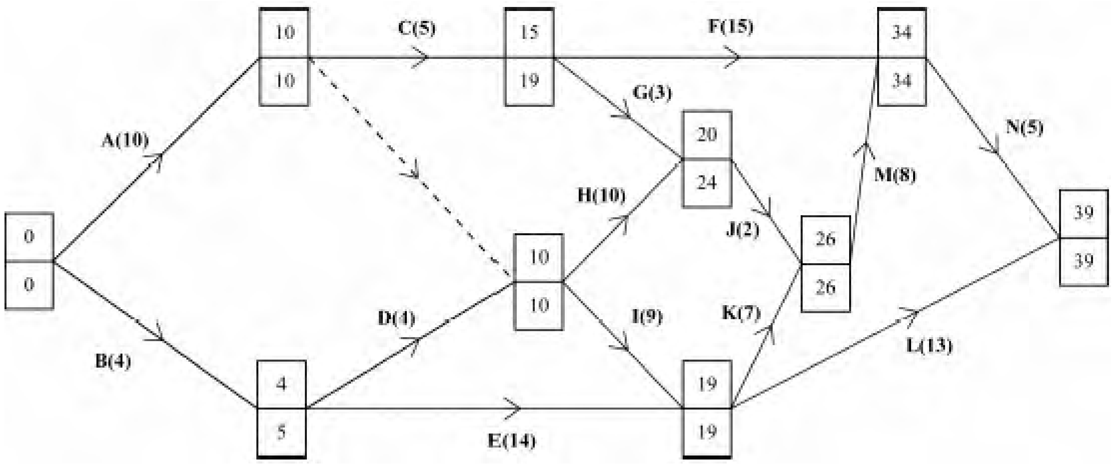
M1,A1 4

(e) 1pm day 16: C B1ft

1pm day 31: C F G H B2ft 1ft 0 3

[15]

4. (a)

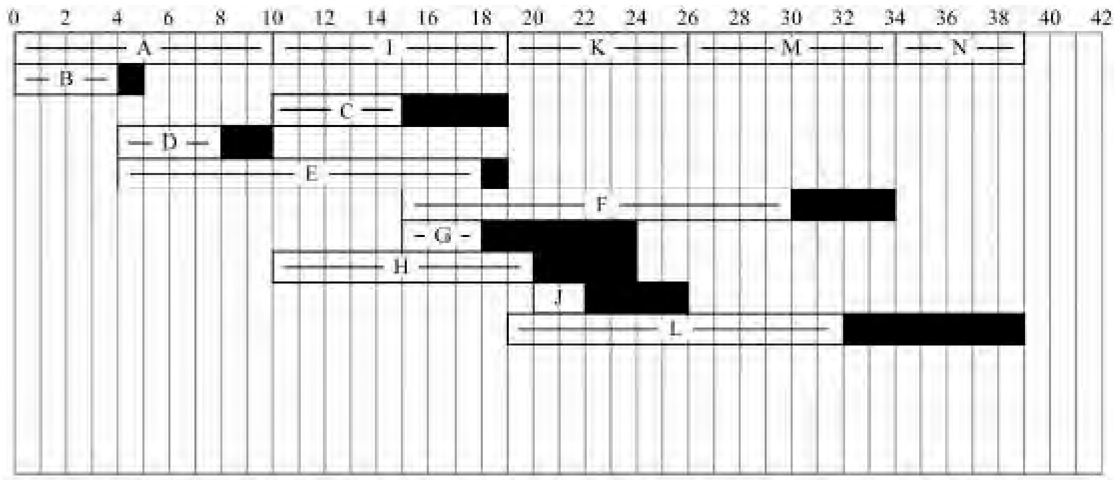


M1 A1 M1 A1 4

(b) A, I, K, M, N; Length 39 B2, 1, 0; B1 3

(c) Float on F is 34 – 15 – 15 = 4 M1 A1
Float on G is 24 – 15 – 3 = 6 B1 3

(d)



M1 A1 M1 A1 4

(e) e.g. At time 14 ½ there are 4 tasks I, E, H and C must be happening. B2, 1, 0 2

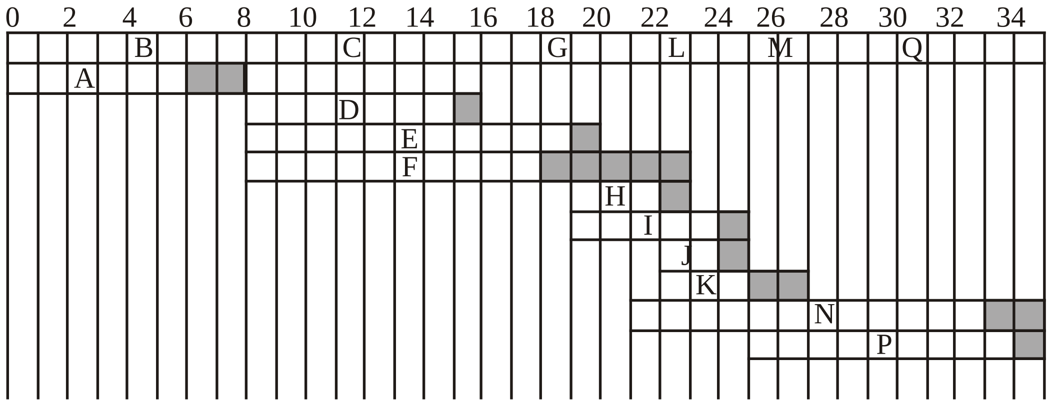
[16]

5. (a) v = 16 w = 25 x = 23 y = 20 z = 8 B3,2,1,0 3

(b) B C G L M Q B1 1

(c) Float on H = 23ft – 19 – 3 = 1 B1
Float on J = 25 – 22 – 2 = 1 B1 2

(d)



M1A1A1A1 4

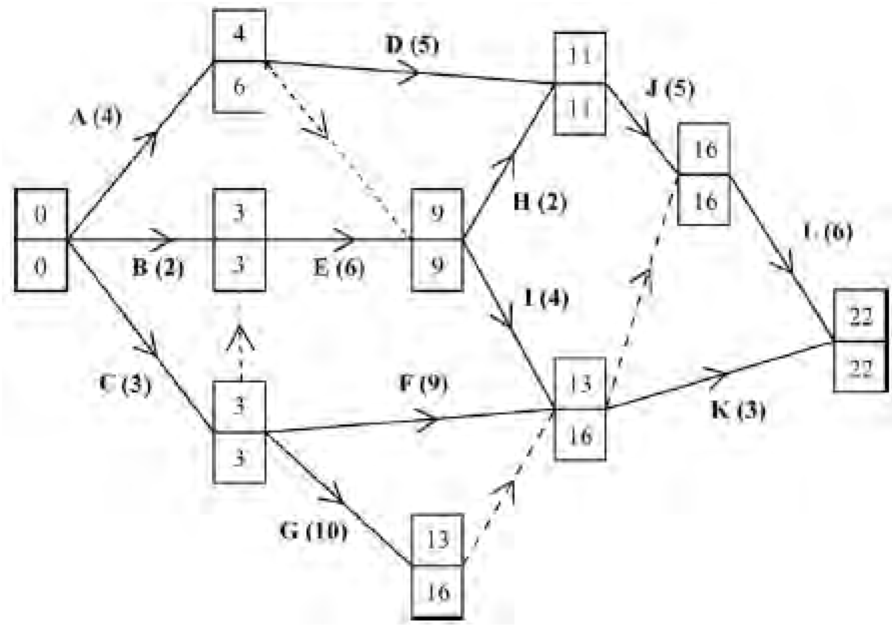
(e) E has one day of float, so project can still be completed on time. B2,1,0 2

(f) e.g.
- At time 23 ½ activities L, I, J and N must be taking place B2,1,0 2
- At time 13 ½ or 14 ½ acitivites C, D, E and F must be taking place

So 4 workers needed.

[14]

6. (a)



M1 A1
M1 A1 4

Note

1M1: Top boxes completed generally increasing left to right.

1A1: CAO.

2M1: Bottom boxes completed generally decreasing right to left.

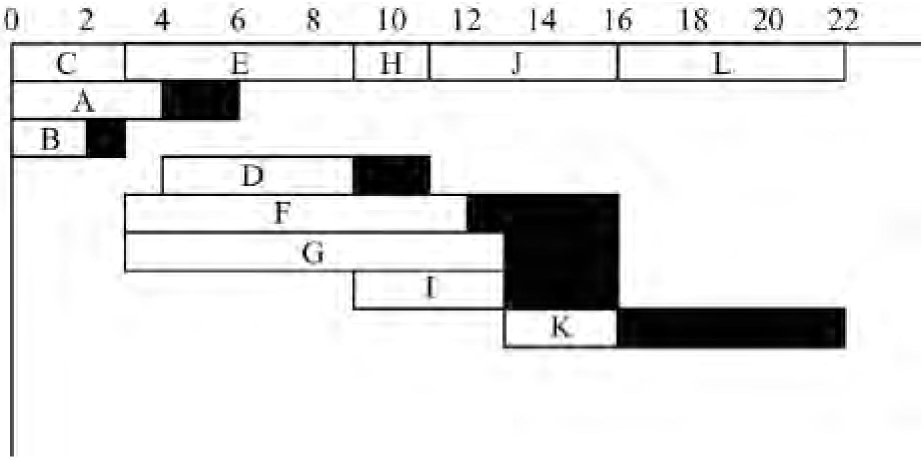
2A1: CAO.

(b) Critical activities: C E H J L B1 1

Note

1B1: Critical activities cao.

(c)



M1 A1
A1 A1 4

Note

1M1: At least 10 activities placed, at least five floats. Scheduling diagram gets M0.
1A1: my critical activities correct.
2A1: condone one error on my non-critical activities.
3A1: my non-critical activities correct.

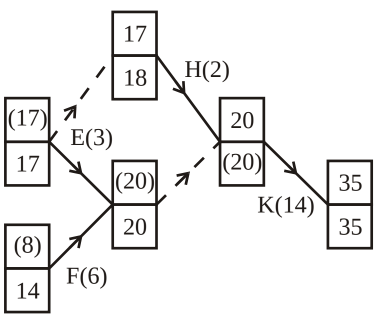
(d) 4 workers needed e.g. at time 8 ½ (noon on day 9) activities E, D, F and G must be happening. B2, 1, 0 2

Note

1B1: A correct statement, details of either time (7<time<9, 8<day<10), or activities, bod gets B1. Allow 1 B mark (only) on ft from their 12 activity, 7 float diagram.
2B1: A correct, complete full statement details of time and activities.

[11]

7. (a) M1A1



M1A1 4

(b) Total float on D = 18ft – 5 – 9 = 4ft M1
G = 25 – 8 – 10 = 7 A2,1ft,0
I = 25 – 20 – 3 = 2 B1 4

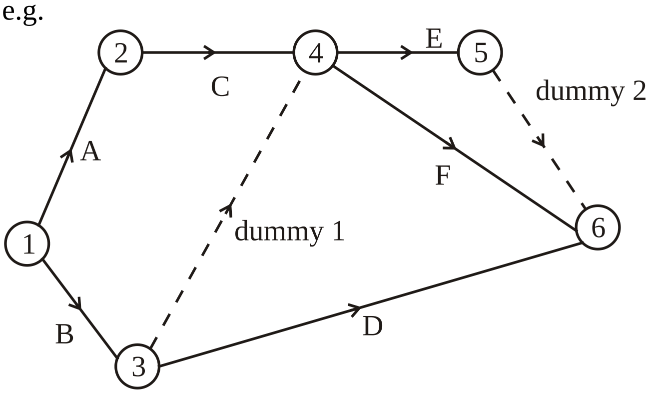
(c) Critical activities: B E J M — B1 — 1

(d) Lower bound = $\frac{102}{35}$ = 2.914 — B1

$\therefore$ 3 workers — B1 — 2

[11]

8. (a) e.g.



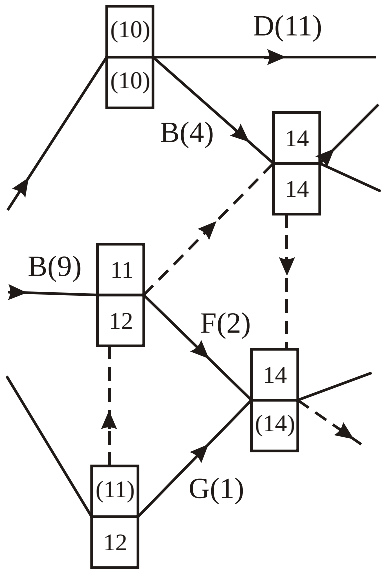
M1A1A1A1 — 4

(b) Dummy 1 is needed to show <u>dependency</u>
E and F depend on C and B, but D depends on B only

Dummy 2 is needed so that each activity can be <u>uniquely</u> represented in terms of its events. — B3,2,1,0 — 3

[7]

9. (a) — B3,2,1,0 — 3



(b) *A E H K* B2,1,0 2
A E L

(c) idea of 'critical' B1
- zero float, no delay, immediate
- if late, project with finish late etc.

idea of 'path'
- from start to end event + continuous B1 2
- the event forming end of one activity forms the start of the next
- sequence or series or links or run....

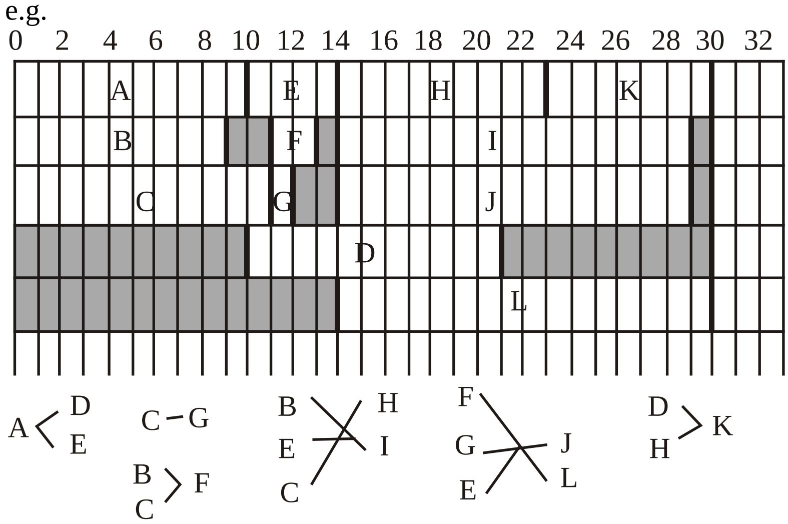
<u>S.C.</u> "longest path" gets B1 only

(d) $\frac{110}{30}(= 3.7 / 3.6)$ $\therefore$ 4 workers M1A1 2

(e) *D*, *H*, *I*, *J*, *L* B2,1,0 2

(f) It will not be possible to find a solution with 4 workers B1 1
to complete the project in the minimum time. 5 workers will
be needed.
Accept "an extra worker is required"

(g) e.g.



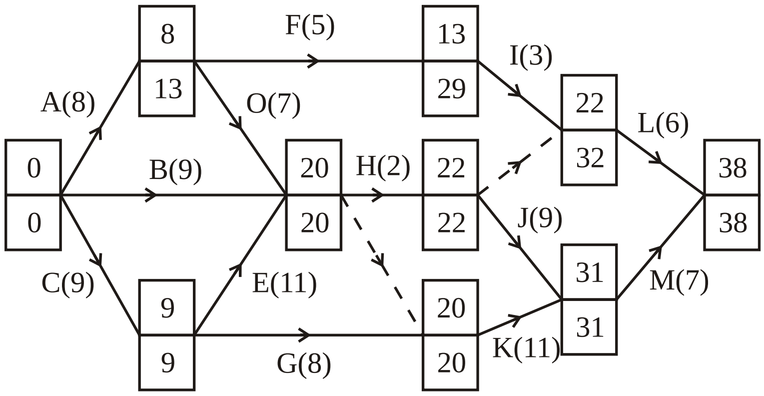
40

M1A1A1 3

[15]

10. (a) J depends on H alone, but L depends on H and I B1 1

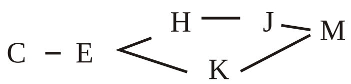
(b)



M1A1
A1A1 4

(c) Total float on D = 20 – 7 – 8 = 5 M1A1ft
Total float on E = 20 – 11 – 9 = 0 A1 3
Total float on F = 29 – 5 – 8 = 16

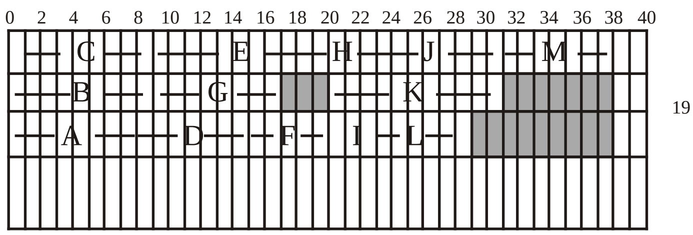
(d)

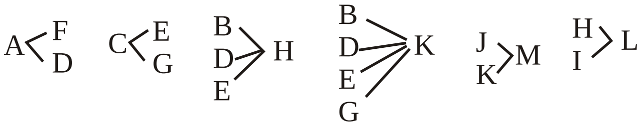


M1A1 2

(e) $\frac{95}{38} = 2.5$ so 3 workers M1A1 2

(f) e.g.

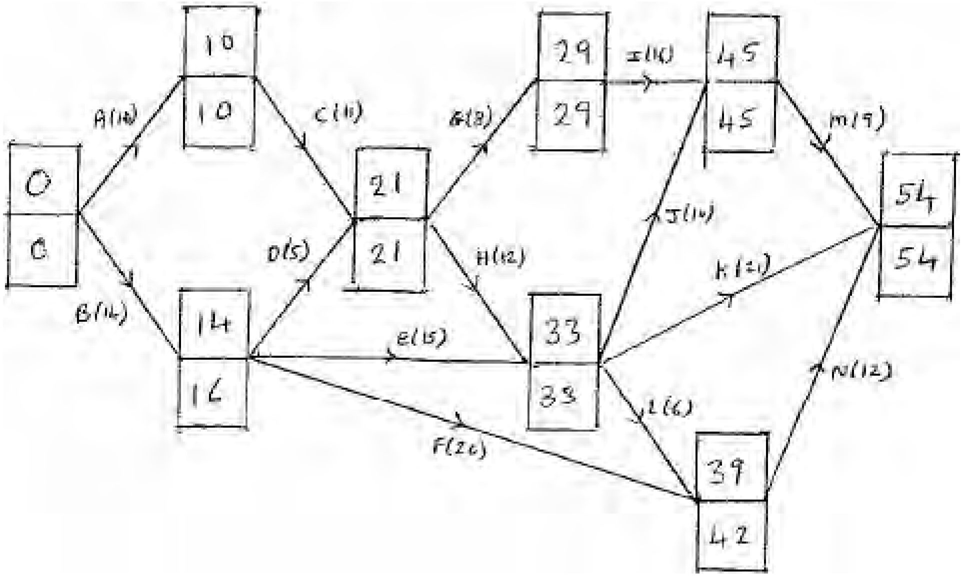




M1A1
A1
A1 4

[16]

11. (a) M1, A1 2



M1 All top boxes completed → increasing generally
A1 c.a.o.
M1 All lower boxes completed → decreasing generally
A1 c.a.o.

(b) A – C – G – I – M; H – K A1 1

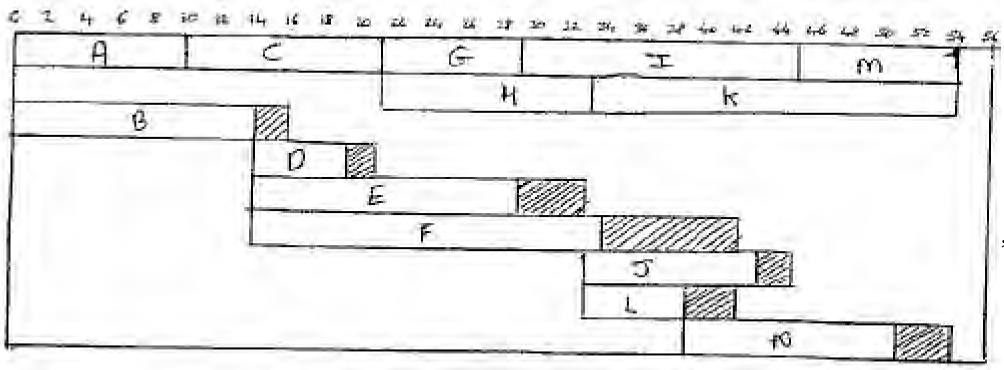
A1 c.a.o. all seven listed – no extras

(c) Float on D = 21 – 5 – 14 = 2 B1ft

Float on F = 42 – 20 – 14 = 8 M1, A1ft 3

B1 ft c.a.o. ft from diagram
M1 method correct or ft correct answer
A1 ft c.a.o. ft from diagram

(d) M1, A1, A1, A1 4



,

M1 At least one of their critical path (must be complete answer) and three non-critical stated including floats

A1 critical activities correct

A1ft Four non-critical activities correct ft from diagram must include a float per activity

A1 c.a.o. on non-critical

(e) Day 15: C B1

B1 c.a.o.

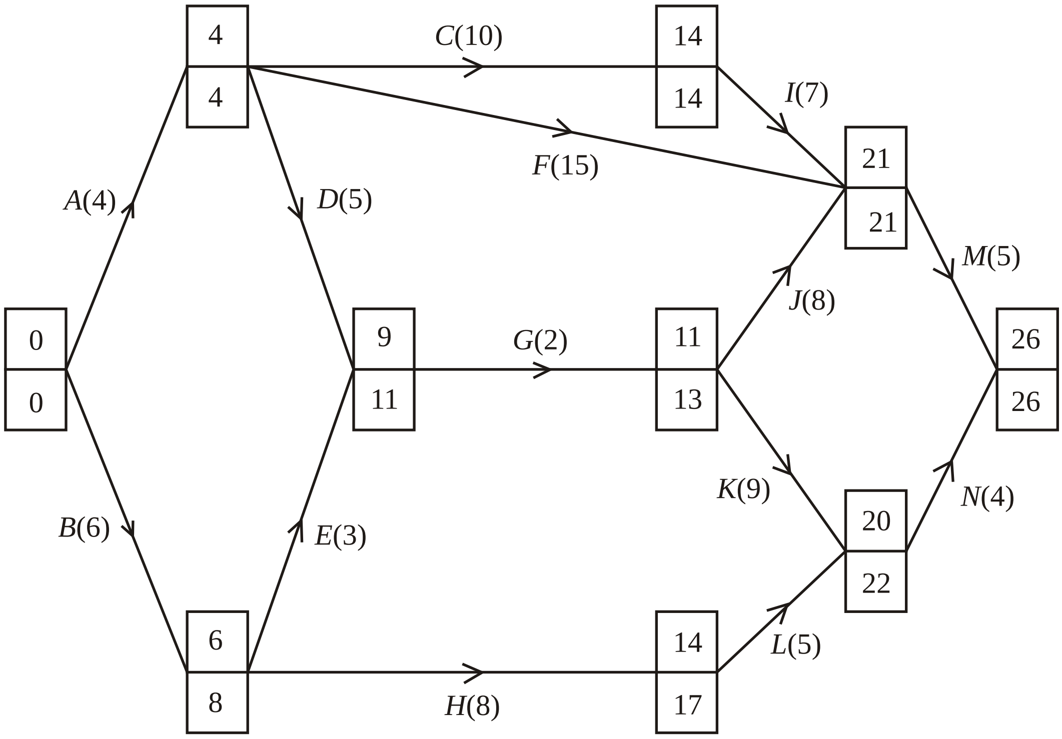
Day 25: G, H, E, F B2,1,0 3

B2 c.a.o.

B1 if one extra or one omission

[15]

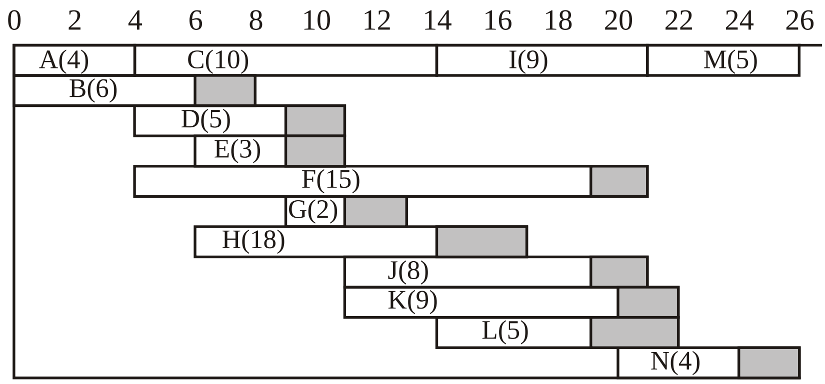
12. (a)



M1 A1
M1 A1 4

(b) A C I M length 26 B1 B1ft 2

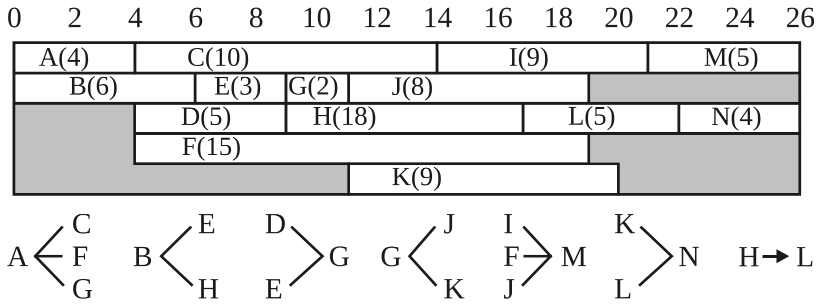
(c)



M1
A3, 2/1/0 4

(d) 5 workers needed e.g. ref to 13.14 when C, F, H, J and K must be taken place B2, 1, 0 2
e.g. ref to 18..19 when I F J K L must be taking place

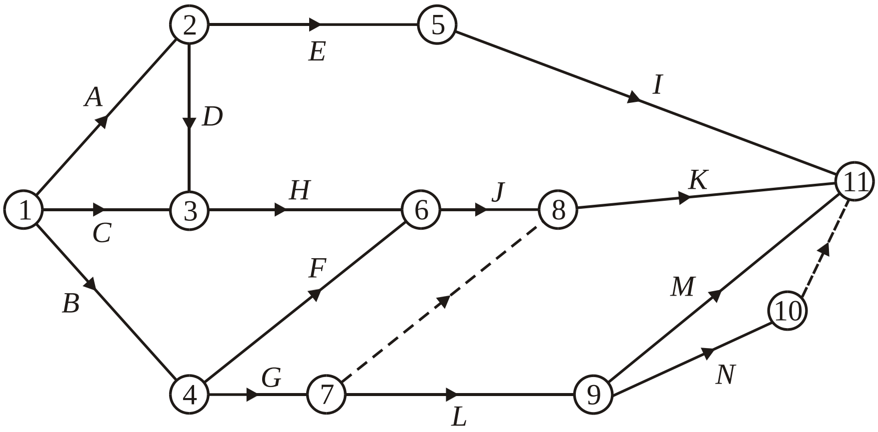
(e) e.g.



M1
A2, 1, 0 3

[15]

13. (a) e.g. M1 A1 A1 A1 4



M1 6 activities + 1 dummy, activity on arc. <u>Condone lack of events throughout</u>

A1 A – F + arcs + 1 start

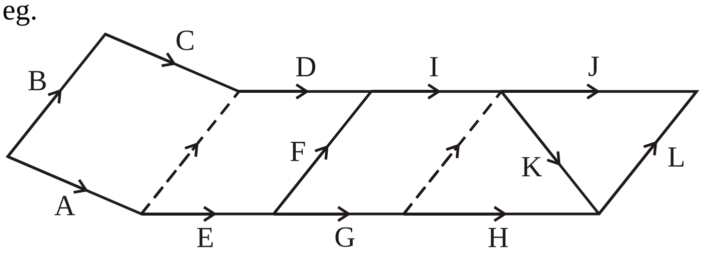
A1 G – K + dummy "7 – 8" (ignore label on dummy) + arrow on dummy + other arcs (penalise once only)

A1 L – N + dummy + 1 finish "10–11" <u>Note:</u> dummy may be M or N (ignore label on dummy) + arrows on dummy+ other arcs (penalise once only)

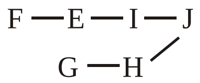
	(b)	Reference to *K*, *J*, *G* and *L* – *K* depends on *J* and *G*, but *L* depends on *G* only	B2,1,0	
		Both *M* and *N* must be uniquely represented in terms of events.	B1	3
		B2 complete + clear K, J, G, L referred to explanation clear + correct		
		B1 nearly there. "Bad" gets B1. All there but confused explanation/vague. K J G L referred to		
		B1 unique representation (o.e.) start + finish at the same events.		

[7]

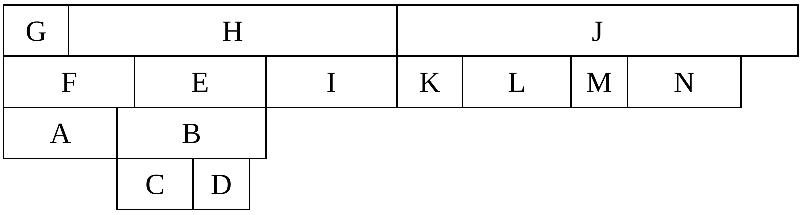
14.	(a)	D depends on A and C, but E depends on A only	B1	
		H depends on G only, but J and K depend on G and I	B1	2
	(b)	eg.	M1 A1 A1 A1 A1	5



[7]

15.	(a)	$x = 12$ y 24 $z = 19$	B3,2,1,0	3
	(b)	Allows J and K to be given a unique representation using events	B1	1
	(c)		M1A1	2
	(d)	No effect, B has a total float of 2	M1A1	2
	(e)	eg • Total of activities = 54, 54 ÷ 24 = 2.25 so 2 workers not enough • 54 ÷ 2 = 27 hours per worker, so 2 workers can not finish in 24 hours • Argument about the activities that need to be completed by t = 7 or 10	B2,1,0	2

(f)



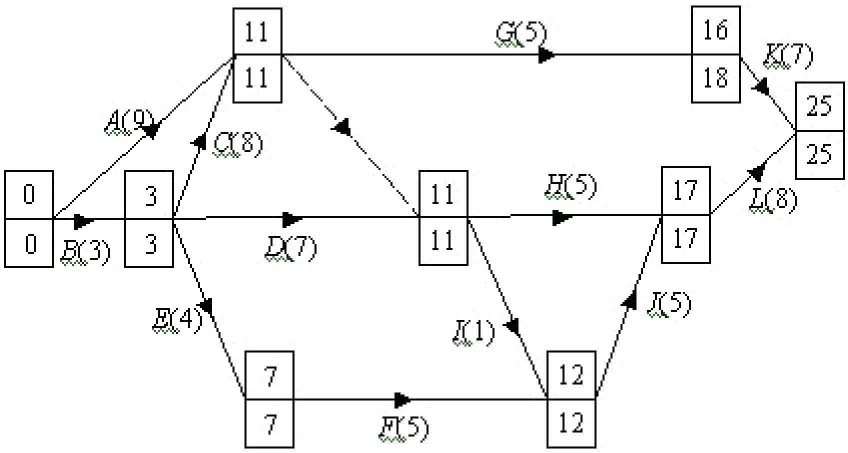
M1A1
A1
A1
A1 5

(g) 10 extra hours ∴ £280 M1A1 2

[17]

16. (a) e.g. - *G* depends on *A* and *C* only but *H* and *I* depend on *A*, *C* and *D*. B1 1

(b)



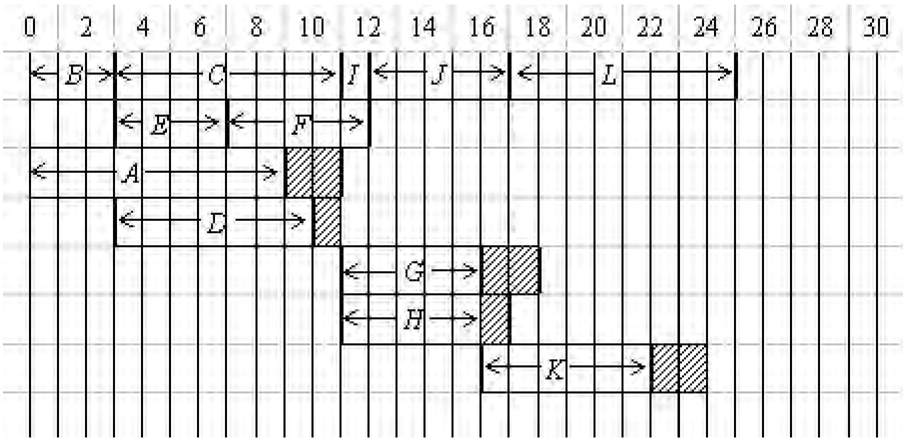
M1A1 M1A1 4

(c) 

so *B*, *C*, *E*, *F*, *I*, *J*, *L* A1 1

(d) *A*: 11 – 0– 9 = 2
D: 11 – 3 – 7 = 1 M1
G: 18 – 11 – 5 = 2 A1ft
H: 17 – 11 – 5 = 1 A1ft 3
K: 25 – 16 – 7 = 2

(e)



M1A1ftA1ftA1 4

(f) <u>Gantt chart</u> eg at time 8 *C*, *F*, *A* and *D* , must be happening M1
$\therefore$ 4 workers needed A1 2

[15]

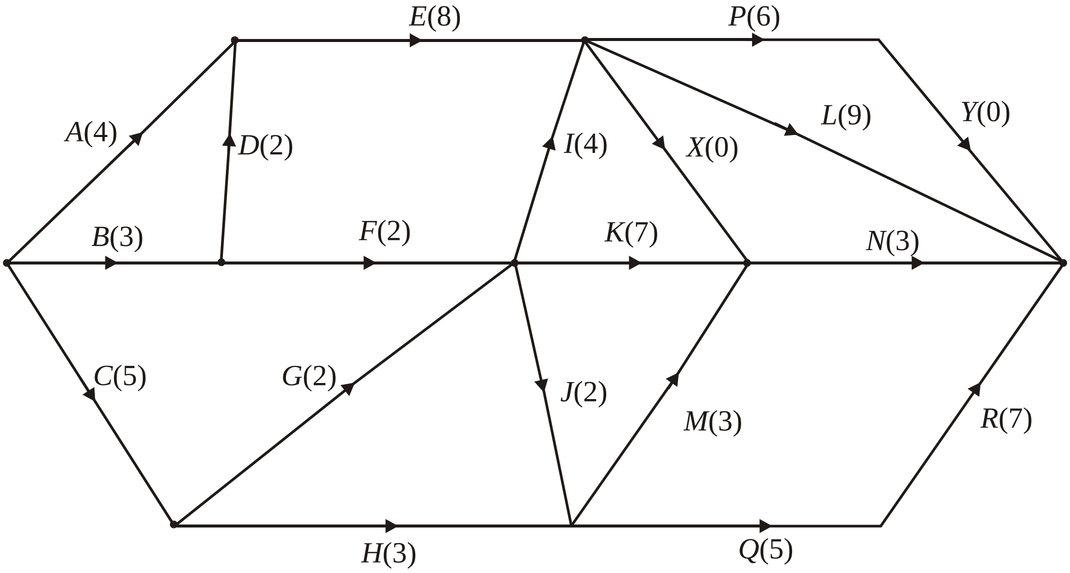
17. (a) $x = 0$, $y = 7$, $z = 9$ B1, B1, B1, 3

(b) Length = 22, critical activities B D E L B1, B1, 2

(c) (i) Float on N = 22 – 14 – 3 = 5 B1

(ii) Float on H = 16 – 5 – 3 = 8 M1 A1 3

(d)

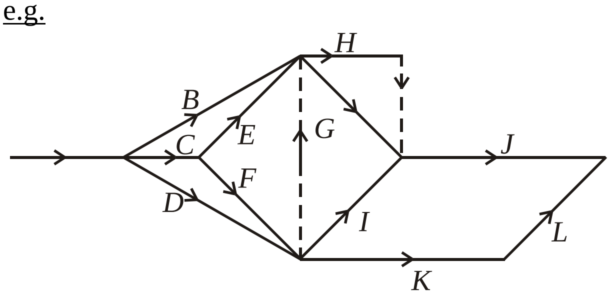


B4, 3,2,1,0 4

(e) Attempt at 1. e.t. and e.e.t. M1
22 hours A1 2

[14]

18. (a) e.g.



M1 A1A1A1A1A1 6

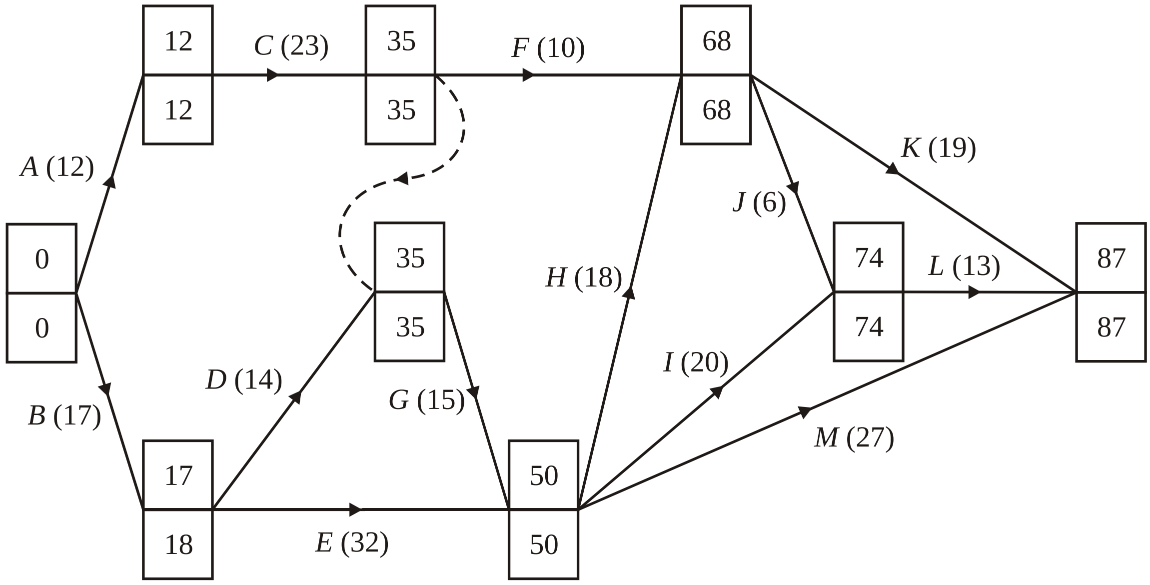
(b) e.g. D will only be critical if it lies on a longest route.

ABEG – 14
ACFG – 15 M1
ACDEG – 13 + x

So D critical if $x \geq 2$ (must be ≥ not >) A1 2

[8]

19. (a)



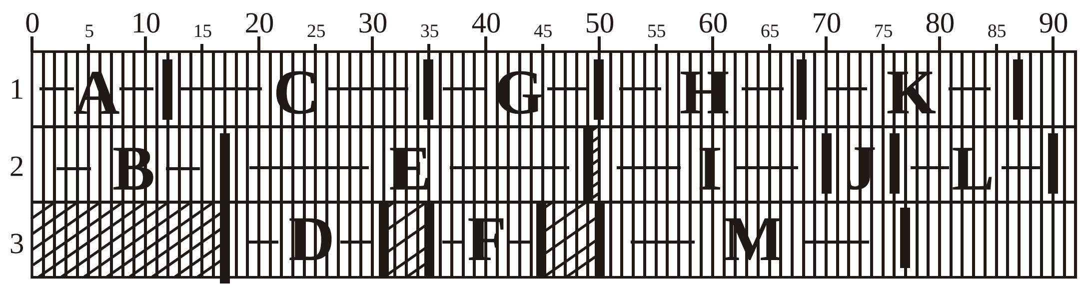
M1 A1 A1 ft A1 4

(b) *A*, *C*, *G*, *H*, *J*, *K*, *L* M1 A1 2

(c) 35 – 17 – 14 = 4 M1 A1 2

(d) <u>either</u> 226 ÷ 87 = 2.6 (1 dp), ∴ 3 workers M1 A1 2
<u>or</u> reference to e.g. 69 hours <u>and</u> J, K, I M ∴ 4 workers

(e) e.g.:



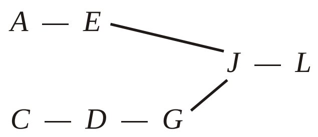
M1 A1 A1 A1

Worker 1: *A C G H K*
Worker 2: *B E I J L*
Worker 3: *D F M*
New shortest time is 89 A1 c.s.o. 5

[15]

20. (a) $x = 31$, $y = 17$ B1 B1 2

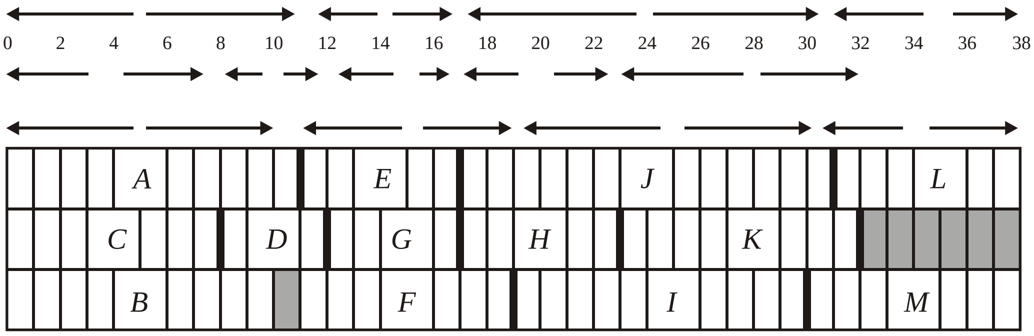
(b) M1 A1 2



(c) $107 \div 38 = 2.8$ (1 d.p.) $\therefore$ 3 workers M1 A1 2

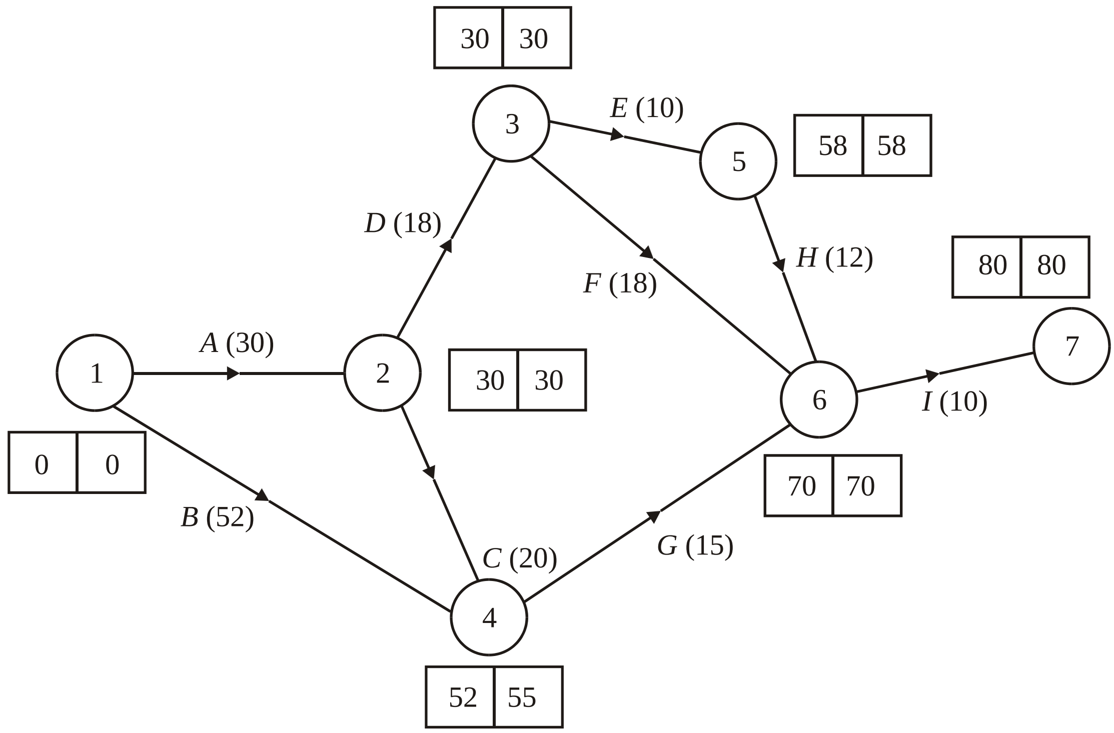
(d) For example,

M1 4



[10]

21. (a)



Early and late event times shown in boxes above. M1 A1 4

(b) The critical path is of length 80 days B1

The critical activities are shown, they are *A*, *D*, *E*, *H* and *I* B1

(c) Floats on non-critical activities:

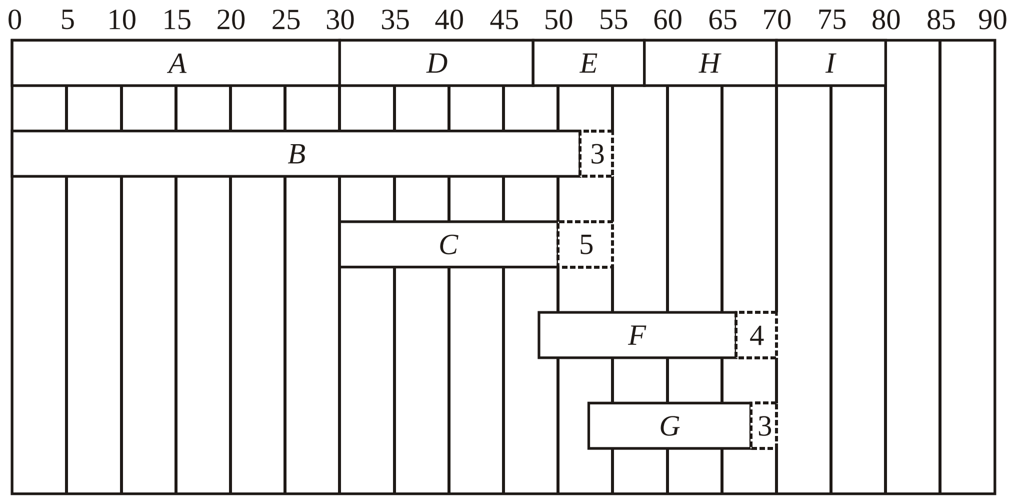
B = 55 – 0 – 53 = 3

C = 55 – 30 – 20 = 5

F = 70 – 48 – 18 = 4

G = 70 –52 – 15 = 3 M1 A1 2

(d)



(e) Worker 1 does *A*, *D*, *E*, *H* and *I* in 80 days. M1

Worker 2 does *B* followed by *G* (ends at 67) A1

Worker 3 does *C* followed by *F* (starting at 50)

So project can be done by 3 workers in critical time of 80 days. A1 3

Now the earliest time at ↓ is 60 M1 A1

⇒ the earliest time at ± is 75

⇒ the earliest time at ″ is 85

so length of critical path is 85.

The critical path is then *A*, *C*, *G* and *I* A1 3

[12]

1. No Report available for this question.

2. Many scored 12 out of 15 marks demonstrating good knowledge and understanding here. Part (a) discriminated well between the many who gained 1 mark and the few who communicated full understanding clearly, to score 2. The majority of candidates achieved at least a mark for 'dummy' or the fact that E was dependent on A and B. The 2nd B mark was often lost because there was no reference to C and D being dependent upon A only. In part (b) most correctly completed the precedence table, with the most frequent errors at G. Almost all filled in all the early times correctly in (c), but there were many errors in the late times, usually a 5 at event 2 and a 9 at event 4 due to a failure to deal correctly with the dummy activities. The cascade charts in part (e) were generally good, with most frequent errors in the floats on A and C arising from (d). Only a few incorrectly attempted schedules, an improvement on previous examinations.

3. This was a challenging question for many, but those candidates who were well-prepared made good progress and some good solutions were seen. Most, but not all, candidates were able to complete part (a) correctly. Most identified the critical activities but many included I as a critical activity. Examiners were pleased that most candidates showed their calculations when determining the length of the total floats, as directed, and most calculated the floats correctly. Some omitted, or made only a token attempt at part (d); others drew a scheduling diagram, but far fewer than in previous years. Many candidates made a good attempt at the cascade diagram and most handled the critical activities correctly. Activities K and M were often omitted, and the floats on F and G were often incorrectly drawn. Only the best candidates completed part (e) correctly. Many omitted C for day 31 and many listed 4 or 5 activities for day 16.

4. Many fully correct responses to part (a) were seen, but some common errors were: 13, 17 or 21 in place of the 19 at the end of C; 6 as the late time at the end of B; 18 instead of 20 as the early time at the end of G, often accompanied by an 8 at the end of the dummy; 14 instead of 10 as the late time at the end of A. Most candidates gave the correct answers in part (b), but B, E and/or L were often included as critical activities. In part (c) most candidates gained full marks, showing the three numbers used in the calculation of each of the floats. Some just stated the value of each float, losing two of the three marks. Many fully correct responses were seen to (d). Most were able to show the critical path correctly in part (d), but errors were often seen associated with activities B, C, D, G and/or L. A number used the diagram for scheduling and scored no marks. Part (e) was often poorly done. Candidates were instructed to use their cascade (Gantt) chart, but many calculated a lower bound and many made an attempt to schedule the activities. Candidates are expected to state a specific time and list the specific activities that must be taking place.

5. This was a challenging question with few scoring full marks, even in part (a), although most were able to gain some credit often in part (b) and (c). Most candidates were able to score at least one mark in (a), although full marks were rarely seen. Part (b) was usually successfully attempted, although some included E as a critical (b) was usually successfully attempted, although some included E as a critical activity. The floats were often calculated correctly in part (c). Many omitted, or made only a token attempt at part (d) others drew a scheduling diagram. Of those who made full attempt most handled the critical activities correctly, but activities A and B were often incorrectly drawn with float being added to B and removed from A. Part (e) was answered well by some but others focussed on activities H I and J etc, rather than just E's total float of 1. Relatively few candidates gained both marks in (f). When using a cascade chart to determine a lower bound, candidates need to state both the time they are looking at and the activities that must be happening then.

6. This question also gave rise to a good spread of marks. The dummies in part (a) caused problems for many, often values 2 and 6 instead of 3 and 3 were seen at the end of the dummy from C and 19 instead of 16 was often seen in the bottom box at the end of the dummy from G. Most were able to correctly identify the critical activities although B often replaced C.

Those candidates who had completed parts (a) and (b) correctly were usually able to complete part (c) correctly. The most common mistakes were having no float on B and having more float than necessary on activities F and G.

Part (d) was rarely completed correctly. In a number of cases candidates stated either a relevant time or the relevant activities but rarely both.

7. This question was usually well done, and a rich source of marks for most candidates. Most were able to gain all four marks in part (a), but the dummies caused problems for some, leading to incorrect numbers at the start of activities E and H. Many calculated the floats in part (b) correctly and showed the three numbers they used to calculate each float as requested, others wasted time creating a table of all the early and late start and finish times and the durations, for all activities, but then did not indicate which numbers they had used to find the floats, so losing marks. Part (c) was usually well-answered but occasionally K was added to the list of critical activities. Most candidates were able find a lower bound of 3, but some attempted a scheduling or tried to draw a Gantt chart, again wasting time, others used an incorrect method such as 35/13.

8. Whilst some very good answers were seen, particularly in part (a) this question proved challenging for many. Common errors in part (a) included: using activity on vertex; lack of arrows; not having a single start and a single finish and most common of all an incorrect second dummy. Many candidates were able to correctly draw activities A to D and place the first dummy but many either omitted the second dummy completely or placed it parallel to the first, but opposite in direction. Similarly in part (b) most candidates were able to explain the need for the first dummy, although the words 'precede' and 'proceed' were either confused or misunderstood. The reason for the second dummy was often omitted, of those who did attempt it the reason was often thought due to their being independent rather than needing to have a unique representation in terms of events.

9. Most candidates identified AEHK as a critical path, but far fewer correctly identified AEL. Most candidates were able to gain marks for the 'critical' part of the definition, often by reference to zero floats, but few addressed the 'path' part correctly. A number thought that a zero float was a consequence of the early and late times being the same. Many used 'flow' instead of 'float', many confused event and activity and arc with node. A number of candidates did not carry out a calculation in (d), and attempted to schedule at this stage, and some divided by the number of activities, but most correctly found the arithmetic lower bound. Part (e) was generally well answered, although some omitted an activity, or included K. Those who correctly completed parts (d) and (e) were usually successful in part (f), although some did not appreciate that their answer to (d) was only a lower bound, and evidently thought that the project had to be completed by only four workers. Although some cascade diagrams were seen, most candidates attempted a scheduling diagram. The most common errors were overlapping C with F, E with J, and length errors.

10. Most candidates knew that the dotted lines represented dummies, and candidates are better able to explain their purpose, but many candidates did not refer to the specific activities involved and tried to explain in terms of events, this was rarely successful. Most candidates completed part (b) correctly although there were a worrying minority that had two different values in the boxes at the final event. Some candidates wasted time calculating the total float for each activity in (c). Many incorrect total float calculations were seen, candidates MUST show their working here if they are to gain full credit. As always a few candidates found the sum of their total floats. Most candidates were able to find 'a path's worth' of critical activities in part (d), but many omitted K, or included G. Most candidates were able to calculate a correct lower bound for the number of workers in part (e), but a surprisingly large minority divided 95 by 13, the number of activities. Disappointingly having discovered that 3 was the lower bound, many candidates used four workers in part (f). Some candidates drew a cascade (Gantt) chart instead of a scheduling diagram. Usually candidates were able to place the critical activities correctly – although K was often placed too early, but there were the usual errors to do with duration, precedence, omission and duplication of activities. Some of the scripts were very difficult to mark because of faint writing, lack of clarity of writing, the size of the letters, the boundaries between the activities being indistinguishable from the grid, heavy shading over the activities and so on.

11. This was a good source of marks for many candidates, but it also discriminated well. In part (a) the most frequent error occurred in calculating the late event at the end of activity B. In part (b) many listed J as a critical activity and some only listed one path's worth of critical activities. Part (c) was very revealing. Candidates were required to show their working and although most used numbers from the correct parts of their diagram many did not. Some subtracted two numbers at one event, others used the two late times or the two early times. Some, predictably, found the sum of their total floats. A surprisingly good number of candidates completed part (d), but many showed no floats, probably trying to draw a scheduling diagram, and others made errors when indicating activity lengths. A significant number overlapped B and D, and L and N so that activity length and floats could not be clearly identified. Again part (e) was surprisingly well-answered by very many candidates. Some listed a few extra activities with C, with D, E and F being popular companions, and a few only listed G and H for day 25.

12. Parts (a) and (b) were often well done – although many made slips such as stating 9 as the late event time for B instead of 8. A few included F as a critical activity. Most candidates were able to draw a cascade chart. There was a variety of techniques used to display the activities and floats, those who drew multiple lines sometimes ran out of space, and candidates using this method may need to return to the top of the chart to show the later activities. Many made slips displaying the lengths of the activities or their floats, and some omitted some activities. Part (d) was poorly answered, candidates were directed to use their cascade chart but few did so. Candidates needed to state a specific time and list all the activities that must be happening at that time. Part (e) was often poorly done with errors of duration and precedence being common, even amongst those using the correct number of workers.

13. This question produced a good range of marks. Most candidates were able to score some marks in part (a) with very few activity on node responses seen. Common errors were: omitting arrows- which is particularly serious on the dummy arcs, adding superfluous dummies - often around D, having multiple start and end points, and omitting the final (MN) dummy. The first dummy was usually correctly drawn and usually well explained in part (b). The uniqueness constraint leading to the second dummy seemed to be less well understood. Some candidates gave a general comment about dummies rather than the specific explanation needed. (On a different note many candidates referred to 'a dummie' rather than 'a dummy' in their explanation).

14. Although some very good answers were seen to part (a) many candidates were not able to give a precise explanation. Many tried to give an answer in general rather than specific terms. The response to part (b) was variable, with some very good and some poor diagrams seen. Common errors were omitting arrows, having more than one end point and making E dependent on C. There is a minority, but still a large number, of candidates using activity on node.

15. Part (a) was usually correctly answered, the only frequently seen error was stating that $y = 12$. Only the best candidates were able to explain the use of the dummy activity in part (b). Most candidates were able to list at least some of the critical activities, some did not list all however and some listed a few non-critical ones too. Just half the candidates were able to answer part (d) correctly and some of those were unable to explain clearly their reason. Some very loose answers were seen to part (e). Candidates must specify the activities and times if they are discussing activities that must take place simultaneously, many incorrect activity totals were seen. Some tired to draw a cascade chart in part (f) but generally this was quite well done, although often not showing the most efficient way possible. In part (g) most candidates realised that they needed 'extra hours' multiplied by £28.

16. Very few candidates were able to answer part (a) completely and correctly. Many candidates were able to gain credit in part (b), but only the better prepared gained full marks. C and I were often omitted as critical activities. Floats were usually correctly calculated and some credit was given for correct working from incorrect diagrams. Some candidates confused 'total float' with the total of the total floats. Many candidates confused Gantt and scheduling diagrams in part (e). Part (f) was rarely answered correctly.

17. Parts (a), (b) and (c) were well answered by the majority of the candidates. In part (d) the dummy from P to the end point was often omitted and arrows were occasionally neglected. In part (e) 75 was often given as the answer this being the total of all the activities.

18. Most candidates were able to make a good start on the diagram – some after an initial attempt had been modified. Dummies were poorly handled by some candidates who omitted arrows, used them unnecessarily to extend B and D, or omitted the one for G/H. Many did not bring their activities to a single end point; some omitted arrows. Very few candidates were able to make much progress in part (b), but some excellent answers were seen from the more able candidates.

19. This was a good discriminator and both some very good and some very poor answers were seen. Many candidates had difficulty dealing with the dummy correctly in part (a). For those with the correct diagram in part (a) parts (b) and (c) were usually correctly done, although some candidates did not make it absolutely clear that they were using $35 - 17 - 14$ to find the total float. In part (d) once again some candidates did not make it clear that they were using $226 \div$ their final time. In part (e) the commonest errors were inaccurate activity times or failing to take note of precedences.

20. Most candidates were able to complete part (a) correctly. Most went on to find at least one critical path in part (b) but only a few identified all of the critical activities. Many candidates were unable to explain convincingly why three workers were needed. The fastest method is to find the lower bound, but the majority of candidates tried to use arguments that hinged on three activities having to take place at the same time. If this was correctly done and the activities and the time they must be simultaneously taking place was stated, credit was given. The majority of candidates who tried to use this argument were too vague, or stated incorrect details – such as the most commonly seen argument *A*, *B* and *C* must all start at time zero.

21. No Report available for this question.