Pearson Edexcel International Advanced Level

Thursday 15 May 2025

Afternoon (Time: 1 hour 30 minutes)

Paper reference **WDM11/01**

Mathematics

International Advanced Subsidiary/Advanced Level
Decision Mathematics D1

You must have:
Decision Mathematics Answer Book (enclosed), calculator

Candidates may use any calculator allowed by Pearson regulations. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

Instructions:

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B). Coloured pencils and highlighter pens must not be used.
- **Fill in the boxes** on the top of the answer book with your name, centre number and candidate number.
- Do not return the question paper with the answer book.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the D1 answer book provided – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Inexact answers should be given to three significant figures unless otherwise stated.

Information:

- There are 8 questions in this question paper. The total mark for this paper is 75.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*

Advice:

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- If you change your mind about an answer, cross it out and put your new answer and any working underneath.

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Write your answers in the D1 answer book for this paper.

1: The list of numbers shown below represents the masses, in kg, of nine items that are to be moved from one factory to another.

180 300 250 410 240 120 230 310 190

The items will all be moved, by van, at the same time.

Each van can carry at most 600 kg.

(a) Calculate a lower bound for the number of vans required.

(2)

(b) Use the first-fit bin-packing algorithm to allocate the items to vans.

(2)

(Total for Question 1 is 4 marks)

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2:

	P	Q	R	S	T	U	V
P	–	105	90	195	270	95	155
Q	105	–	195	295	370	190	255
R	90	195	–	110	185	180	245
S	195	295	110	–	75	115	170
T	270	370	185	75	–	180	245
U	95	190	180	115	180	–	65
V	155	255	245	170	245	65	–

The table shows the least distances, in metres, between seven signposts, P, Q, R, S, T, U and V.

Aisha must visit each signpost to check that it has not been damaged. She needs to find a route which minimises the distance travelled, starting and finishing at P.

(a) Use Prim's algorithm, starting at P, to obtain a minimum spanning tree for the network. You must clearly show the order in which you select arcs.

(2)

(b) Use the answer to part (a) to obtain an initial upper bound for the length of Aisha's route.

(2)

(c) Use the nearest neighbour algorithm, starting at P, to find a second upper bound for the length of Aisha's route. You should state both the route and its length.

(3)

(d) By deleting T and all of its arcs, and using the answer to part (a), obtain a lower bound for the length of Aisha's route.

(2)

(Total for Question 2 is 9 marks)

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3:

(i) A list of twelve numbers is to be sorted into **ascending** order.

28 18 50 27 48 8 25 12 56 31 33 42

(a) Use a quick sort to obtain the sorted list. You should show the result of each pass and identify your pivots clearly.

(4)

(b) Show how the binary search algorithm is used to try to locate the number 40 in the list. You must clearly indicate your choice of pivots and which part of the list you are rejecting.

(3)

(ii) A different list of nine distinct integers is to be sorted into **descending** order.

23 20 x 32 15 8 19 6 22

The list is sorted using bubble sort. The first three passes are

23 20 32 x 15 19 8 22 6

23 32 20 x 19 15 22 8 6

32 23 20 19 x 22 15 8 6

Determine the range of possible values of x

(2)

(Total for Question 3 is 9 marks)

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4:

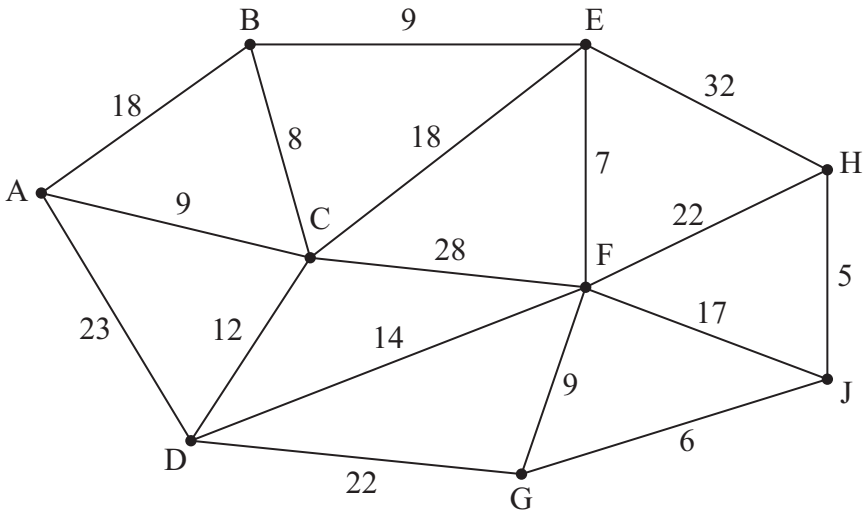


Figure 1

Figure 1 represents a network of roads between nine villages, A, B, C, D, E, F, G, H and J. The number on each arc is the time taken, in minutes, to drive along the corresponding road.

Liliya must drive from village A to village H.

(a) (i) Use Dijkstra's algorithm to determine the fastest route from A to H.

(ii) State the fastest time.

(6)

The roads EF and GJ are now closed for maintenance.

(b) Calculate how much more time Liliya's drive will now take.

(2)

(Total for Question 4 is 8 marks)

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5: A gardener wants to plant some rose bushes. She will use three different colours, red, yellow and white.
The gardener decides to use linear programming to determine how many of each colour she will plant.

Let x represent the number of red rose bushes, y represent the number of yellow rose bushes and z represent the number of white rose bushes.

The gardener wants to maximise the total number of rose bushes she will plant.

(a) Write down the objective for this problem.

(1)

The gardener has a total of £1400 available to spend. Given that

- red rose bushes cost £12.50 each
- yellow rose bushes cost £10 each
- white rose bushes cost £15 each

(b) show that one constraint is given by

$$5x + 4y + 6z \leqslant 560$$

(2)

The gardener decides that

- the number of red rose bushes must be at least 40% of the total number of rose bushes
- there must be at least three white rose bushes for every two yellow rose bushes

(c) Use this information to formulate two further constraints, which should be fully simplified with integer coefficients.

(3)

The gardener decides to plant exactly 30 white rose bushes. This reduces two of the constraints to

$$5x + 4y \leqslant 380$$
$$y \leqslant 20$$

(d) Show that the third constraint can be reduced to

$$3x - 2y \geqslant 60$$

(2)

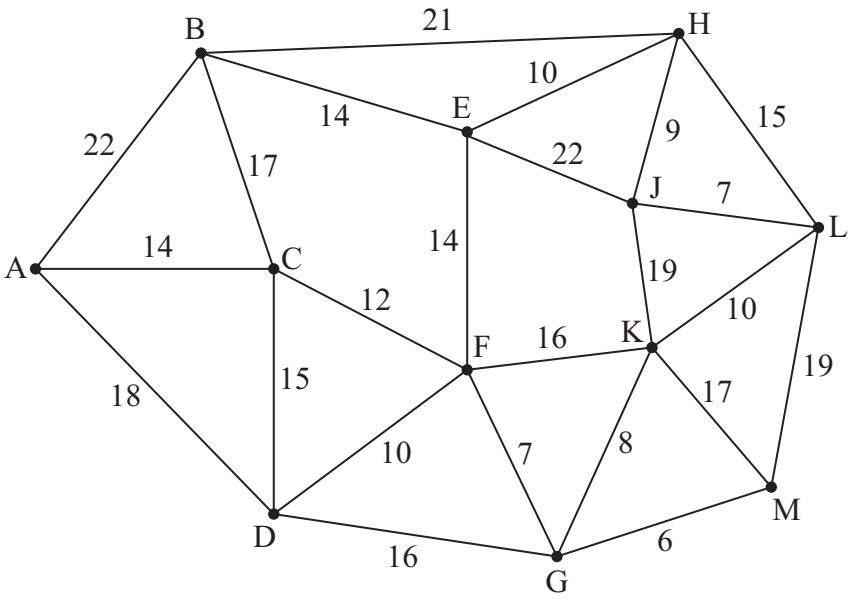
(e) Draw these three constraints using the axes in the answer book and hence determine the number of red rose bushes and the number of yellow rose bushes that the gardener will plant.

(4)

(Total for Question 5 is 12 marks)

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6:



[*The total length of the network is 338*]

Figure 2

Figure 2 represents a network of roads connecting a group of villages. The number on each arc is the length, in km, of the corresponding road.

Bolin needs to inspect the network in Figure 2. He must travel along each road at least once, minimising the length of his route.

Bolin's route must **start** at A and **finish** at J.

(a) Determine the length of Bolin's route. You must make your method clear and state the roads which need to be repeated.

(5)

A new road is constructed from F to J which has length 18 km. Bolin must inspect the changed network, starting at A and finishing at J. He must travel along each road at least once, minimising the length of his route.

(b) Determine the change to the length of Bolin's route.

(2)

(Total for Question 6 is 7 marks)

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7:

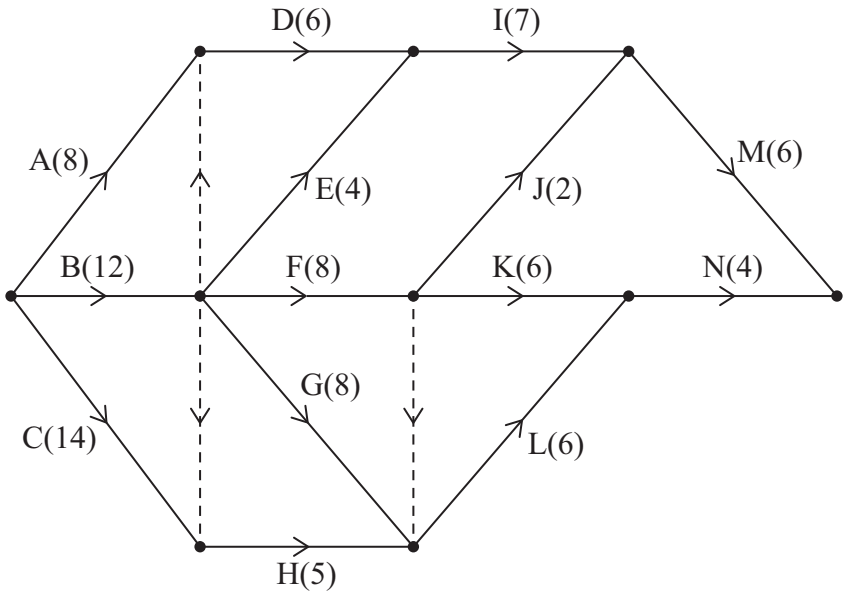


Figure 3

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

(a) Complete the precedence table in the answer book to show the immediately preceding activities for the project.

(3)

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

(4)

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

(2)

(d) Draw a Gantt (cascade) chart on the grid in the answer book.

(4)

(e) Use the Gantt chart to determine the minimum number of workers required to complete the project in the minimum time. You must make specific reference to the number of workers, activities and times.

(3)

(Total for Question 7 is 16 marks)

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Turn over for Question 8

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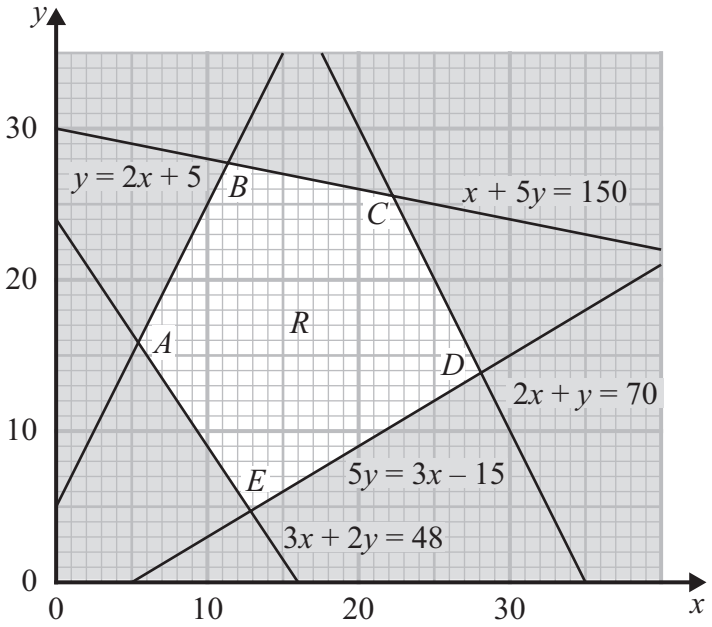


Figure 4

The feasible region, R, of a linear programming problem is shown in Figure 4.
The boundaries form part of the feasible region.
The regions excluded from the feasible region have been shaded.

Given that one of the constraints is

$$3x + 2y \geqslant 48$$

(a) state the remaining four constraints.

(2)

Question 8 continues on page 11

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The five vertices of the feasible region are labelled A, B, C, D and E

An objective function is of the form

$$P = ax + by$$

where a and b are integers.

This objective function has

- a minimum value of $202\frac{5}{7}$ at vertex E
- a maximum value of $576\frac{2}{3}$ at vertex C

(b) Determine the value of a and the value of b, making your working clear.

(4)

A **different** objective function is of the form

$$Q = x + ky$$

where k is a positive constant.

This objective function has a minimum value at vertex A and a maximum value at vertex C

(c) Determine the range of values of k, making your working clear.

(4)

(Total for Question 8 is 10 marks)

TOTAL FOR PAPER IS 75 MARKS

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Mathematics

International Advanced Subsidiary/Advanced Level
Decision Mathematics D1

Answer Book

Do not return the question paper with the answer book.

Total Marks

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1:

180 300 250 410 240 120 230 310 190

(a) Total mass = 180 + 300 + 250 + 410 + 240 + 120 + 230 + 310 + 190

= 2230 kg

2230 ÷ 600 = 3.716...

Lower bound = 4 vans

(b) First-fit bin packing (items taken in the order given):

Van 1: 180 300 120 (total 600)

Van 2: 250 240 (total 490)

Van 3: 410 190 (total 600)

Van 4: 230 310 (total 540)

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Question 1 continued

180 300 250 410 240 120 230 310 190

(Total for Question 1 is 4 marks)

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2:

	P	Q	R	S	T	U	V
P	–	105	90	195	270	95	155
Q	105	–	195	295	370	190	255
R	90	195	–	110	185	180	245
S	195	295	110	–	75	115	170
T	270	370	185	75	–	180	245
U	95	190	180	115	180	–	65
V	155	255	245	170	245	65	–

(a) Prim's algorithm starting at P.

Arcs in the order selected:

PR (90), PU (95), UV (65), PQ (105), RS (110), ST (75)

Weight of MST = 90 + 95 + 65 + 105 + 110 + 75 = 540 m

(b) Initial upper bound = 2 × 540 = 1080 m

(c) Nearest neighbour starting at P:

P – R (90), R – S (110), S – T (75), T – U (180),

U – V (65), V – Q (255), Q – P (105)

Route: P – R – S – T – U – V – Q – P

Length = 90 + 110 + 75 + 180 + 65 + 255 + 105 = 880 m

(d) Delete T: the MST from (a) without arc ST (T is a leaf)

is an MST of the remaining nodes, weight 540 – 75 = 465

Two least arcs from T: TS (75) and TU (180)

Lower bound = 465 + 75 + 180 = 720 m

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Question 2 continued

	P	Q	R	S	T	U	V
P	–	105	90	195	270	95	155
Q	105	–	195	295	370	190	255
R	90	195	–	110	185	180	245
S	195	295	110	–	75	115	170
T	270	370	185	75	–	180	245
U	95	190	180	115	180	–	65
V	155	255	245	170	245	65	–

(Total for Question 2 is 9 marks)

3:

28 18 50 27 48 8 25 12 56 31 33 42

(i)(a) Quick sort, pivot = middle item (right of middle):

												Pivot(s)
28	18	50	27	48	8	25	12	56	31	33	42	25
18	8	12	25	28	50	27	48	56	31	33	42	8, 56
8	18	12	25	28	50	27	48	31	33	42	56	12, 48
8	12	18	25	28	27	31	33	42	48	50	56	(18), 31, (50)
8	12	18	25	28	27	31	33	42	48	50	56	27, 42
8	12	18	25	27	28	31	33	42	48	50	56	

Sorted: 8 12 18 25 27 28 31 33 42 48 50 56

(b) Using the sorted list (positions 1 to 12):

Pivot 1: (1 + 12)/2 = 6.5 → 7th item = 31

40 > 31, so reject 31 and all items before it (1st to 7th)

Pivot 2: (8 + 12)/2 = 10 → 10th item = 48

40 < 48, so reject 48 and all items after it (10th to 12th)

Pivot 3: (8 + 9)/2 = 8.5 → 9th item = 42

40 < 42, so reject 42

Pivot 4: 8th item = 33

40 ≠ 33, reject 33; no items remain

So 40 is not in the list.

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P 7 6 4 0 8 A 0 6 2 0
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Question 3 continued

Question 3 continued

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Question 3 continued

23	20	x	32	15	8	19	6	22
23	20	32	x	15	19	8	22	6
23	32	20	x	19	15	22	8	6
32	23	20	19	x	22	15	8	6

(ii) Pass 1: 20 and x were compared and not swapped, so $x < 20$

x and 15 were compared and not swapped, so $x > 15$

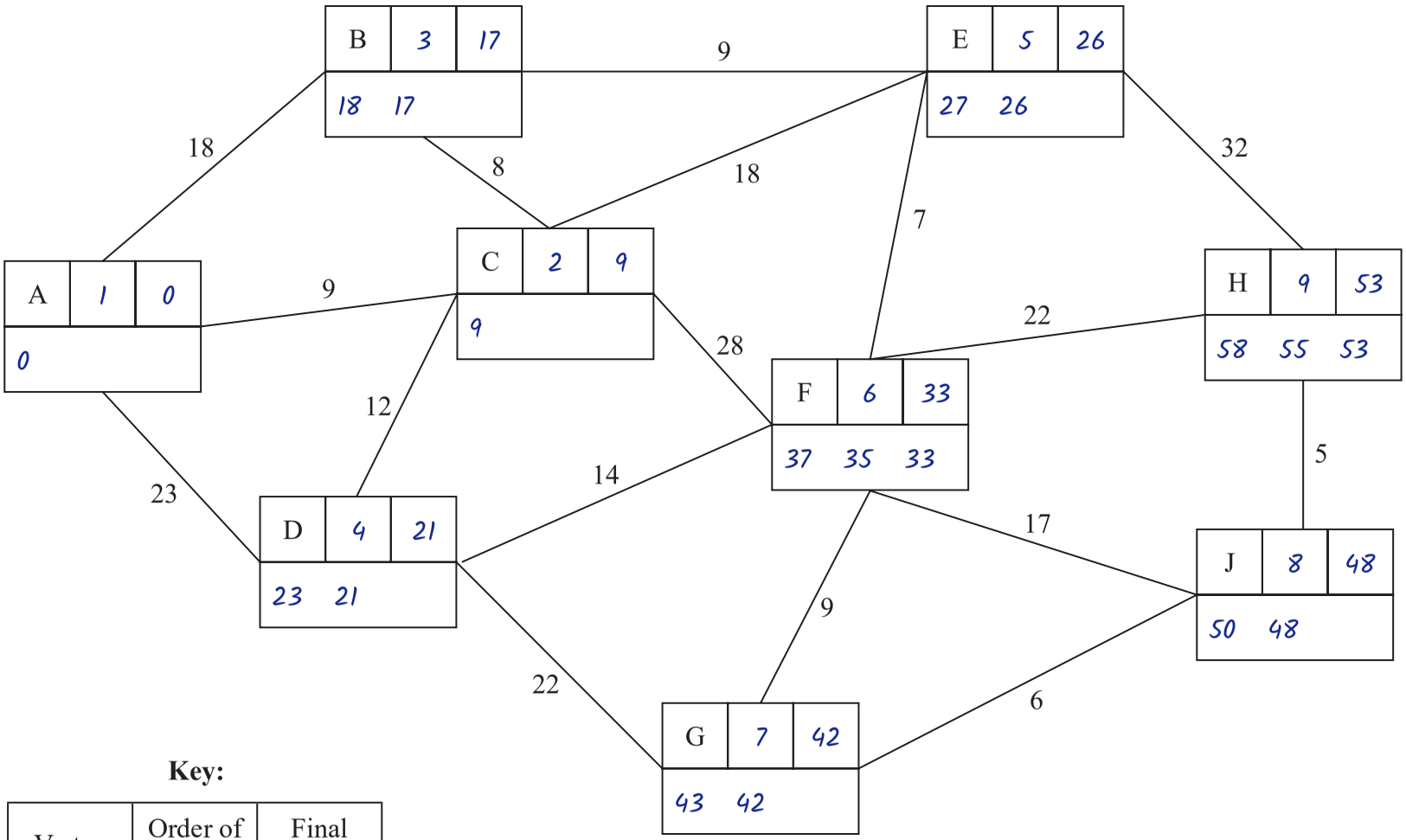
Pass 3: x and 19 were compared and swapped, so $x < 19$

Hence $15 < x < 19$, i.e. $16 \leqslant x \leqslant 18$ ($x = 16, 17$ or 18)

(Total for Question 3 is 9 marks)

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4:



Key:

Vertex	Order of labelling	Final value
Working values		

(i) Fastest route from A to H A – C – B – E – F – G – J – H

(ii) Fastest time 53 minutes

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Question 4 continued

(a)(i) Fastest route: A – C – B – E – F – G – J – H

(ii) Fastest time = 53 minutes

(b) With EF and GJ closed:

Shortest A to F: A – C – D – F = 9 + 12 + 14 = 35

Shortest F to H: F – H = 22 (or F – J – H = 17 + 5 = 22)

(Via E instead: A – C – B – E – H = 26 + 32 = 58, longer)

New fastest time = 35 + 22 = 57 minutes (A – C – D – F – H)

Extra time = 57 – 53 = 4 minutes

(Total for Question 4 is 8 marks)

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5:

(a) Maximise $P = x + y + z$

(b) $12.50x + 10y + 15z \leq 1400$

$\div 2.5$: $5x + 4y + 6z \leq 560$ (as required)

(c) $x \geq 0.4(x + y + z)$ i.e. $x \geq (40/100)(x + y + z)$

$10x \geq 4x + 4y + 4z$

$6x \geq 4y + 4z$

$3x \geq 2y + 2z$

At least 3 white for every 2 yellow: $z/y \geq 3/2$

$3y \leq 2z$

(d) Substitute $z = 30$ into $3x \geq 2y + 2z$:

$3x \geq 2y + 2 \times 30$

$3x \geq 2y + 60$

$3x - 2y \geq 60$ (as required)

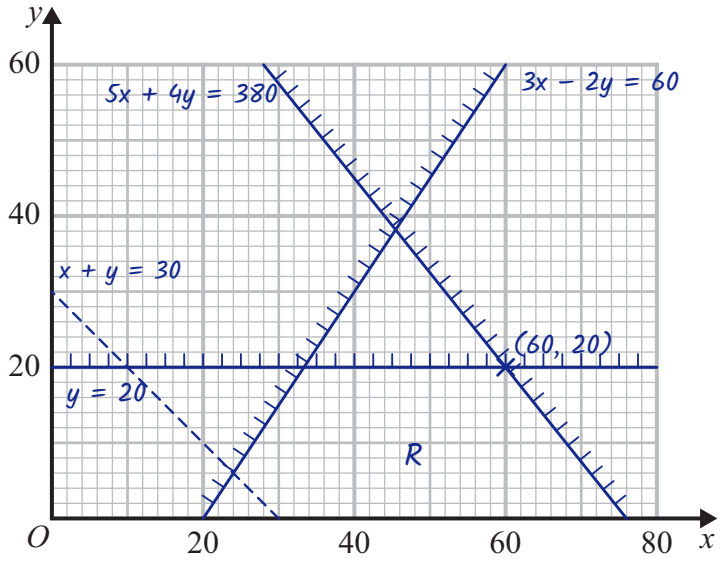
(e) See graph on the next page.

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Question 5 continued



(e) Lines: $y = 20$; $5x + 4y = 380$ through (60, 20) and (76, 0);
$3x - 2y = 60$ through (20, 0) and (40, 30). Unwanted regions hatched.
Vertices of R: (20, 0), (76, 0), (60, 20), (33.3, 20)
Objective: maximise $x + y$ ($z = 30$ is fixed)
at (76, 0): $x + y = 76$
at (60, 20): $x + y = 80$ (largest)
at (33.3, 20): 53.3, at (20, 0): 20
Optimal point (60, 20):
She will plant 60 red rose bushes and 20 yellow rose bushes
(and 30 white rose bushes).

(Total for Question 5 is 12 marks)

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6:

(a) Orders: A = 3, F = 5, K = 5, M = 3 (odd); J = 4 (even), all other vertices are even.

The route starts at A and finishes at J, so A is left unpaired and J must be paired. Odd vertices to pair: F, J, K and M

FJ + KM = 32 + 14 = 46 (FGKLJ, KGM)

FK + JM = 15 + 26 = 41 (FGK, JLM)

FM + JK = 13 + 17 = 30 (FGM, JLK)

Least pairing: FM + JK = 30

Roads to repeat: FG, GM, JL and LK

Length of route = 338 + 30 = 368 km

(b) New road FJ (18 km): F now has order 6 (even) and J has order 5 (odd). Odd vertices are now A, J, K and M.

Start at A, finish at J, so only K and M need pairing:

KM = 14 (KGM): repeat KG and GM

New length = 338 + 18 + 14 = 370 km

Change: 370 − 368 = 2, so the route increases by 2 km

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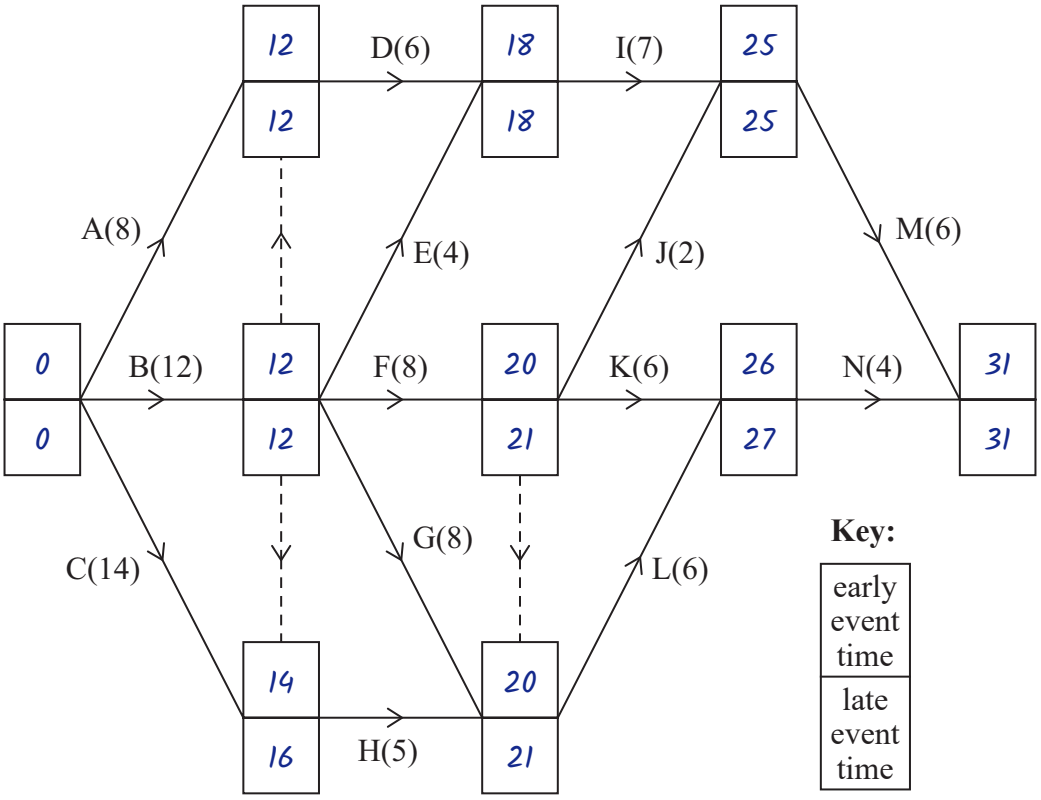
Question 6 continued

(Total for Question 6 is 7 marks)

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7:

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



(c) Sum of activity times = 8 + 12 + 14 + 6 + 4 + 8 + 8 + 5 + 7 + 2 + 6 + 6 + 6 + 4 = 96

Lower bound = 96 ÷ 31 = 3.096...

So at least 4 workers are needed (lower bound = 4)

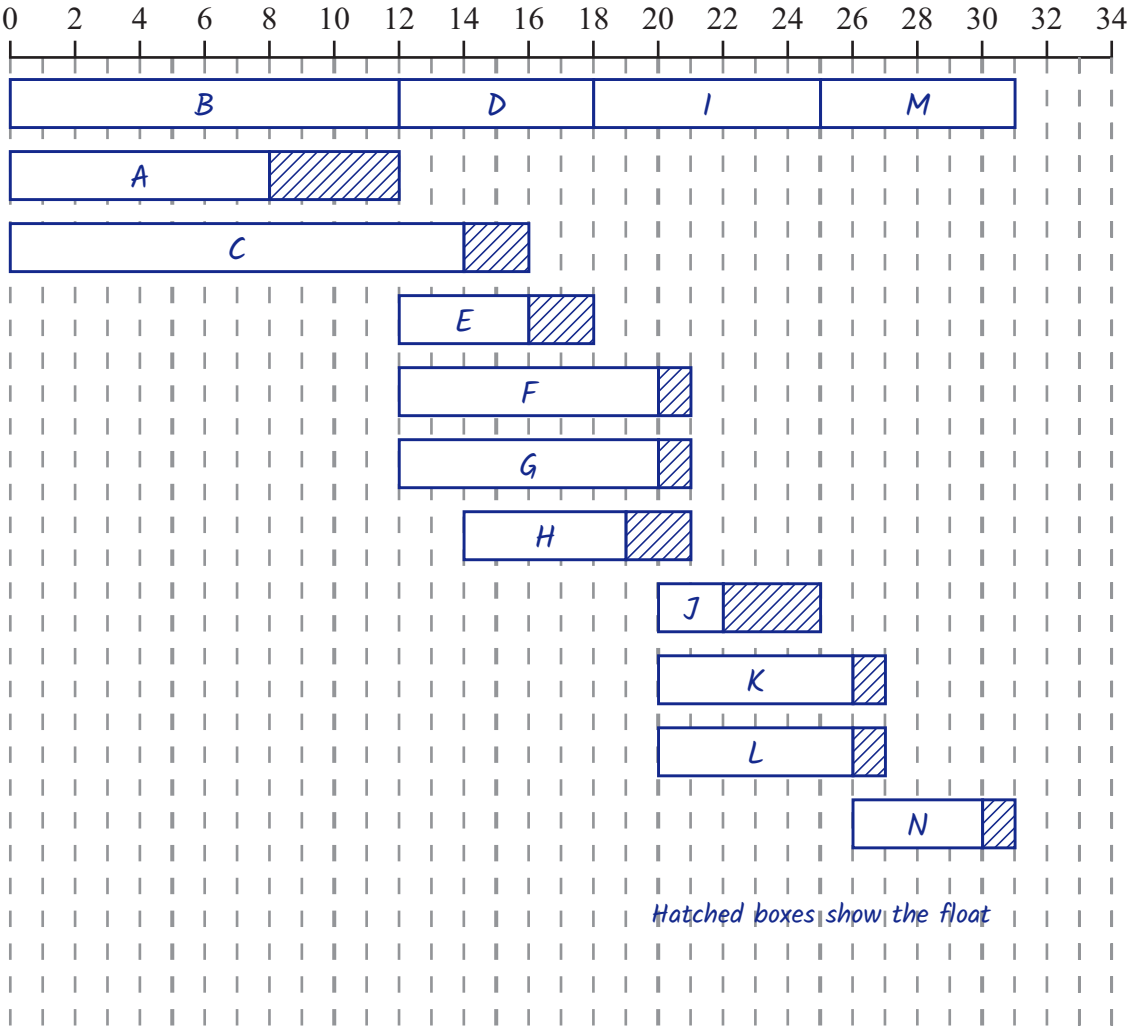
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Question 7 continued

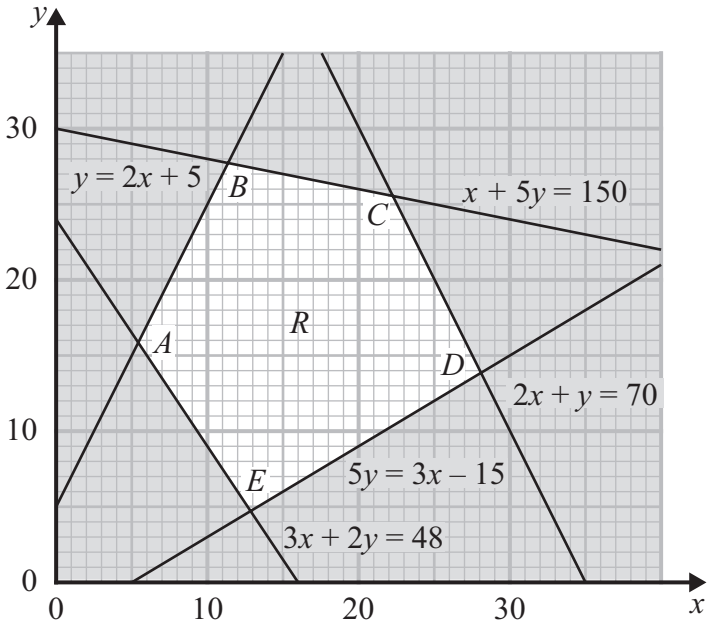
(d)



(e) At time 13.5 (13 < t < 14) activities C, D, F and G must all be happening, and at time 16.5 (16 < t < 17) activities D, F, G and H must all be happening.
Activity E (duration 4, between times 12 and 18) must also be happening either during 13 < t < 14 or during 16 < t < 17.
So 5 activities must happen at the same time at some point:
minimum number of workers = 5

(Total for Question 7 is 16 marks)

8:



(a) $y \leq 2x + 5$

$x + 5y \leq 150$

$2x + y \leq 70$

$5y \geq 3x - 15$

(b) E: $3x + 2y = 48$ and $5y = 3x - 15$

$3x = 5y + 15 \Rightarrow 5y + 15 + 2y = 48 \Rightarrow 7y = 33$

$y = 33/7$, $3x = 165/7 + 15 = 270/7 \Rightarrow x = 90/7$

E (90/7, 33/7)

C: $x + 5y = 150$ and $2x + y = 70$

$y = 70 - 2x \Rightarrow x + 350 - 10x = 150 \Rightarrow 9x = 200$

$x = 200/9$, $y = 70 - 400/9 = 230/9$

C (200/9, 230/9)

At E: $(90/7)a + (33/7)b = 1419/7 \Rightarrow 30a + 11b = 473$

At C: $(200/9)a + (230/9)b = 5190/9 \Rightarrow 20a + 23b = 519$

×2: $60a + 22b = 946$, ×3: $60a + 69b = 1557$

subtract: $47b = 611 \Rightarrow b = 13$

$30a = 473 - 143 = 330 \Rightarrow a = 11$

$a = 11$, $b = 13$ $(P = 11x + 13y)$

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Question 8 continued

(c) A: $3x + 2y = 48$ and $y = 2x + 5$

$3x + 4x + 10 = 48 \Rightarrow x = 38/7,\ y = 111/7$

D: $2x + y = 70$ and $5y = 3x - 15$

$350 - 10x = 3x - 15 \Rightarrow x = 365/13,\ y = 180/13$

Minimum at A (not E): $Q(A) < Q(E)$

$38/7 + (111/7)k < 90/7 + (33/7)k$

$38 + 111k < 90 + 33k \Rightarrow 78k < 52 \Rightarrow k < 2/3$

Maximum at C (not D): $Q(C) > Q(D)$

$200/9 + (230/9)k > 365/13 + (180/13)k$

$\times 117$: $2600 + 2990k > 3285 + 1620k$

$1370k > 685 \Rightarrow k > 1/2$

(Equivalently, the gradient $-1/k$ of Q lies between the gradients of $3x + 2y = 48$ $(-3/2)$ and $2x + y = 70$ (-2).)

Range: $1/2 < k < 2/3$

Question 8 continued

(Total for Question 8 is 10 marks)

TOTAL FOR PAPER IS 75 MARKS

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