4.6 Decision: Linear Programming and Critical Path Depth: Test Pack

EDEXCEL 9FM0 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question tests key vocabulary used across linear programming and critical path analysis.

(a) State what is meant by a 'shadow price' associated with a binding constraint in a linear programming problem. **(1)**

(b) State what is meant by 'crashing' an activity in a critical path analysis. **(1)**

(c) State what is meant by a 'basic feasible solution' in the simplex method. **(1)**

(d) State what is meant by 'resource levelling'. **(1)**

(Total for Question 1 is 4 marks)

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2 A project consists of activities A, B, C, D, E, F, G. Each activity is listed with its duration in days and the activities that must be completed before it can start: A (duration 7, after none); B (duration 7, after A); C (duration 6, after B); D (duration 3, after A, B); E (duration 8, after A); F (duration 3, after B); G (duration 5, after C).

(a) Carry out a forward pass to find the earliest start time of each activity, and state the minimum completion time of the project. **(3)**

(b) Carry out a backward pass and hence find the critical activities. **(3)**

(c) Find the total float of activity D. **(2)**

(d) Find a lower bound for the number of workers needed to complete the project in the minimum time, if each activity needs one worker. **(2)**

(Total for Question 2 is 10 marks)

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3 A project consists of activities A, B, C, D, E, F, G, H. Each activity is listed with its duration in days and the activities that must be completed before it can start: A (duration 8, after none); B (duration 2, after A); C (duration 9, after A); D (duration 7, after B); E (duration 6, after C); F (duration 4, after B); G (duration 2, after B); H (duration 6, after F, G).

(a) Carry out a forward pass to find the earliest start time of each activity, and state the minimum completion time of the project. **(3)**

(b) Carry out a backward pass and hence find the critical activities. **(3)**

(c) Find the total float of activity B. **(2)**

(d) Find a lower bound for the number of workers needed to complete the project in the minimum time, if each activity needs one worker. **(2)**

(Total for Question 3 is 10 marks)

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4 A project consists of activities A, B, C, D, E, F, G, H, I. Each activity is listed with its duration in days and the activities that must be completed before it can start: A (duration 9, after none); B (duration 7, after A); C (duration 9, after A); D (duration 8, after C); E (duration 7, after B); F (duration 3, after B, E); G (duration 2, after A); H (duration 5, after C); I (duration 3, after B, D).

(a) Carry out a forward pass to find the earliest start time of each activity, and state the minimum completion time of the project. **(3)**

(b) Carry out a backward pass and hence find the critical activities. **(3)**

(c) Find the total float of activity B. **(2)**

(d) Find a lower bound for the number of workers needed to complete the project in the minimum time, if each activity needs one worker. **(2)**

(Total for Question 4 is 10 marks)

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5 A farmer plants x hectares of wheat and y hectares of barley. The constraints are $2x + 3y \leq 35$, $4x + 3y \leq 49$, $x \geq 0$ and $y \geq 0$. The profit, in hundreds of pounds, is $P = 6x + y$, and the profit is to be maximised.

(a) Draw the feasible region and find the coordinates of each of its vertices. **(3)**

(b) Evaluate P at each vertex and hence find the maximum profit and the values of x and y which give it. **(3)**

(Total for Question 5 is 6 marks)

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6 A factory makes x units of product P and y units of product Q each week. The constraints are $4x + 3y \leq 47$, $2x + 4y \leq 36$, $x \geq 0$ and $y \geq 0$. The profit, in hundreds of pounds, is $P = 2x + 6y$, and the profit is to be maximised.

(a) Draw the feasible region and find the coordinates of each of its vertices. **(3)**

(b) Evaluate P at each vertex and hence find the maximum profit and the values of x and y which give it. **(3)**

(Total for Question 6 is 6 marks)

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Mark scheme · 4.6 Decision: Linear Programming and Critical Path Depth: Test Pack

Question 1

(a) the amount by which the optimal value of the objective function would improve (increase, for maximising) per one extra unit of that resource made available (oe) **B1**

(a) Answer: The improvement in the optimal objective value per one extra unit of that resource.

(b) reducing an activity's duration below its normal time, usually at an increased cost, in order to shorten the project's overall completion time (oe) **B1**

(b) Answer: Reducing an activity's duration below its normal time, usually at extra cost, to shorten the project.

(c) a feasible solution in which the non-basic variables are set to zero, and the basic variables take the values read directly from the right-hand side of the tableau (oe) **B1**

(c) Answer: A feasible solution with non-basic variables at zero, and basic variables read from the tableau's right-hand side.

(d) rearranging the scheduling of activities, using their available float, so as to smooth out (reduce the peaks and troughs of) the demand for a resource over the life of the project, without increasing the overall project duration (oe) **B1**

(d) Answer: Rearranging activities within their float to smooth out resource demand, without lengthening the project.

Question 2

(a) earliest start = latest earliest finish of the immediate predecessors **M1**

(a) earliest starts: A 0, B 7, C 14, D 14, E 7, F 14, G 20 **A1**

(a) minimum completion time = 25 days **A1**

(a) Answer: 25 days

(b) latest finish = smallest latest start of the successors **M1**

(b) latest finishes: A 7, B 14, C 20, D 25, E 25, F 25, G 25 **A1**

(b) critical activities (zero float): A, B, C, G **A1**

(b) Answer: A, B, C, G

(c) total float = latest finish - earliest start - duration **M1**

(c) 25 - 14 - 3 = 8 days **A1**

(c) Answer: 8 days

(d) total duration of all activities = 39 **M1**

(d) 39/25 = 1.56, so at least 2 workers **A1**

(d) Answer: 2

Question 3

(a) earliest start = latest earliest finish of the immediate predecessors **M1**

(a) earliest starts: A 0, B 8, C 8, D 10, E 17, F 10, G 10, H 14 **A1**

(a) minimum completion time = 23 days **A1**

(a) Answer: 23 days

(b) latest finish = smallest latest start of the successors **M1**

(b) latest finishes: A 8, B 13, C 17, D 23, E 23, F 17, G 17, H 23 **A1**

(b) critical activities (zero float): A, C, E **A1**

(b) Answer: A, C, E

(c) total float = latest finish - earliest start - duration **M1**

(c) 13 - 8 - 2 = 3 days **A1**

(c) Answer: 3 days

(d) total duration of all activities = 44 **M1**

(d) 44/23 = 1.91, so at least 2 workers **A1**

(d) Answer: 2

Question 4

(a) earliest start = latest earliest finish of the immediate predecessors **M1**

(a) earliest starts: A 0, B 9, C 9, D 18, E 16, F 23, G 9, H 18, I 26 **A1**

(a) minimum completion time = 29 days **A1**

(a) Answer: 29 days

(b) latest finish = smallest latest start of the successors **M1**

(b) latest finishes: A 9, B 19, C 18, D 26, E 26, F 29, G 29, H 29, I 29 **A1**

(b) critical activities (zero float): A, C, D, I **A1**

(b) Answer: A, C, D, I

(c) total float = latest finish - earliest start - duration **M1**

(c) 19 - 9 - 7 = 3 days **A1**

(c) Answer: 3 days

(d) total duration of all activities = 53 **M1**

(d) 53/29 = 1.83, so at least 2 workers **A1**

(d) Answer: 2

Question 5

(a) plots both constraint lines and shades the unwanted region **M1**

(a) finds the intercepts with the axes and the intersection of the two lines **M1**

(a) vertices: (0, 0), (0, 35/3), (7, 7), (49/4, 0) **A1**

(a) Answer: (0, 0), (0, 35/3), (7, 7), (49/4, 0)

(b) evaluates P at each vertex **M1**

(b) values: 0, 35/3, 49, 147/2 **A1**

(b) maximum P = 147/2 at (49/4, 0) **A1**

(b) Answer: P = 147/2 at (49/4, 0)

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Question 6

(a) plots both constraint lines and shades the unwanted region **M1**

(a) finds the intercepts with the axes and the intersection of the two lines **M1**

(a) vertices: (0, 0), (0, 9), (8, 5), (47/4, 0) **A1**

(a) Answer: (0, 0), (9, 0), (8, 5), (47/4, 0)

(b) evaluates P at each vertex **M1**

(b) values: 0, 54, 46, 47/2 **A1**

(b) maximum P = 54 at (0, 9) **A1**

(b) Answer: P = 54 at (0, 9)

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