

GCE

Further Mathematics A

Y534/01: Discrete Mathematics

AS Level

Mark Scheme for June 2025

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING

RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training: OCR Essential Guide to Marking*.
2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are available in RM Assessor
3. Log-in to RM Assessor and mark the **required number** of practice responses (“scripts”) and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.
2. Marks awarded must relate directly to the marking criteria.
3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.
4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.
5. **Crossed-Out Responses**
Where a candidate has crossed out a response and provided a clear alternative then the crossed-out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed-out response where legible.

Rubric Error Responses – Optional Questions

Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM Assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple-Choice Question Responses

When a multiple-choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).

When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses

When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only one mark per response)

Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth two or more marks)

If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space).

Longer Answer Questions (requiring a developed response)

Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add the annotation 'SEEN' to confirm that the work has been seen and mark any responses using the annotations in section 11.

7. There is a NR (**No Response**) option. Award NR (No Response):

- if there is nothing written at all in the answer space
- OR if there is a comment which does not in any way relate to the question (e.g., 'can't do', 'don't know')
- OR if there is a mark (e.g., a dash, a question mark) which is not an attempt at the question.

Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The RM Assessor **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.
10. For answers marked by levels of response: Not applicable in F501
To determine the level – start at the highest level and work down until you reach the level that matches the answer
To determine the mark within the level, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
Consistently meets the criteria for this level	At top of level

11. Annotations

Annotation	Meaning
✓ and ✕	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
BP	Blank Page
Seen	
Highlighting	

Other abbreviations in mark scheme	Meaning
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only one previous M mark
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This question included the instruction: In this question you must show detailed reasoning.

Subject Specific Marking Instructions

- a. Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)

- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

- b. An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct solutions leading to correct answers are awarded full marks but work must not always be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly. Correct but unfamiliar or unexpected methods are often signalled by a correct result following an apparently incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

If you are in any doubt whatsoever you should contact your Team Leader.

- c. The following types of marks are available.

M

A suitable method has been selected and applied in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words “Determine” or “Show that”, or some other indication that the method must be given explicitly.

A

Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B

Mark for a correct result or statement independent of Method marks.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

- d. When a part of a question has two or more ‘method’ steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation ‘dep*’ is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.
- e. The abbreviation FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only – differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, what is acceptable will be detailed in the mark scheme. If this is not the case please, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be ‘follow through’. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

- f. We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so.
- When a value is **given** in the paper only accept an answer correct to at least as many significant figures as the given value.
 - When a value is **not given** in the paper accept any answer that agrees with the correct value to **3 s.f.** unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
- NB for Specification B (MEI) the rubric is not specific about the level of accuracy required, so this statement reads “2 s.f”.

Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.

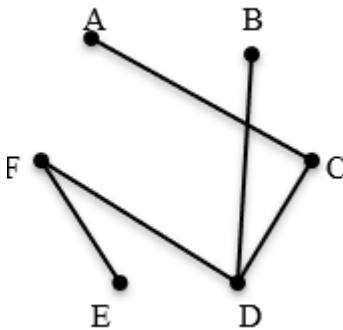
Candidates using a value of 9.80, 9.81 or 10 for g should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

- g. Rules for replaced work and multiple attempts:
- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
 - If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
 - If a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.
- h. For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate’s data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors. If a candidate corrects the misread in a later part, do not continue to follow through. Note that a miscopy of the candidate’s own working is not a misread but an accuracy error.
- i. If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers, provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold “In this question you must show detailed reasoning”, or the command words “Show” or “Determine”. Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.
- j. If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	AO	Guidance
1	(a)		4.5 3.5 3 2.5 2 2 1.5 Length/bin 1: 4.5, 1.5 Length/bin 2: 3.5, 2.5 Length/bin 3: 3, 2 Length/bin 4: 2 Total of the seven lengths = 19, which is more than 3×6, so 3 lengths are not enough 4 (6m) lengths needed	M1 A1* A1 dep * [3]	1.1 1.1 1.1	Sort into (decreasing) order eg 4.5, 3.5, 3, 2 sorted correctly (soi, eg from packing) Correct allocation for first fit decreasing (no bin labelling needed, but allocation must be in the correct order and must be consistent eg may be shown vertically starting from bottom of bins) 4 stated, from correct allocation, need not explain why it cannot be done using fewer
	(b)		Provides a valid solution quickly but may not be optimal	B1 [1]	1.2	Any correct statement that implies either that the solution may not be the optimum or that the runtime is short (eg ‘approximate solution’ or ‘efficient way of getting a good solution’)
	(c)		$\left(\frac{1000}{200}\right)^2$ or 5^2 seen oe $3.2 \times 25 = 80$ seconds or 1 min 20 seconds	M1 A1 [2]	1.1 2.2b	Attempt to use the fact that FFD is of quadratic order (eg $3.2 = k(200)^2 \Rightarrow k = 0.00008$ and $0.00008(1000)^2 = 80$) 80 oe (units may be implied) SC B1 for 80 with no method seen

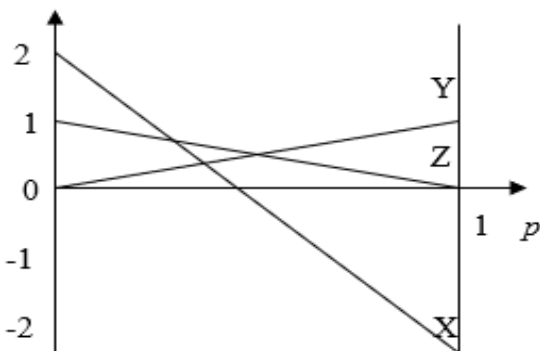
Question			Answer	Marks	AO	Guidance
2	(a)		There are three groupings of cards that sum to 7 i.e. (1 6), (2 5), (3 4)	M1	2.1	Identify the three pigeonholes
			4 cards are chosen but only 3 pigeonholes so by the Pigeonhole Principle, there must be at least two cards from one group	A1	2.2a	Statement comparing the number of choices with the number of pigeonholes
				[2]		
2	(b)	(i)	6×5	M1	1.1	Correct method used to determine number of options (6×5 or 6P2 or $2 \times 6C2$ or using factorial notation)
			$= 30$	A1	1.1	SC B1 answer 30 without valid method seen
				[2]		

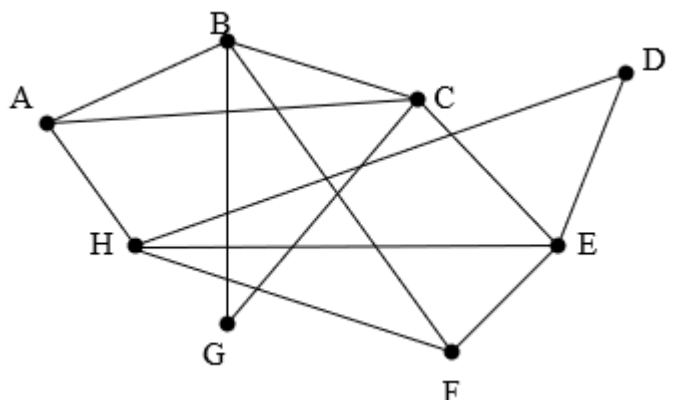
Question			Answer	Marks	AO	Guidance
2	(b)	(ii)	Units digit must be even (eg 2,4 or 6) = 3 choices For each of these there are 5 choices for the tens digit 3×5 15 possibilities	M1 A1	3.1a 2.2a	Consider units digit first, 3 choices and 5 choices Appropriate calculation oe leading to answer 15
			Alternative method 1 Half the numbers in (b)(i) are even and the other half are odd 30 divided by 2 15 possibilities	M1 A1		Identify that half the numbers found are even eg by symmetry their (a) divided by 2 Appropriate calculation oe leading to answer 15
			Alternative method 2 If tens digit is odd (1, 3, 5), there are three options for units digit, $3 \times 3 = 9$ possibilities If tens digit is even (2, 4, 6), there are two options for units digit, $3 \times 2 = 6$ possibilities $9 + 6$ 15 possibilities	M1 A1		Considering these pairs or any coherent argument that gives 9 possibilities and 6 possibilities Appropriate calculation oe leading to answer 15
			Alternative method 3 12, 14, 16, 24, 26, 32, 34, 36, 42, 46, 52, 54, 56, 62, 64 15 possibilities	M1 A1		Listing at least 13 possibilities Listing all 15 with no repeats and stating 15
				[2]		

3	(a)	<table><tr><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr><tr><td>A</td><td>-</td><td>5</td><td>3</td><td>5</td><td>8</td><td>10</td></tr><tr><td>B</td><td>5</td><td>-</td><td>6</td><td>②</td><td>7</td><td>5</td></tr><tr><td>C</td><td>③</td><td>6</td><td>-</td><td>1</td><td>10</td><td>8</td></tr><tr><td>D</td><td>5</td><td>2</td><td>①</td><td>-</td><td>9</td><td>4</td></tr><tr><td>E</td><td>8</td><td>7</td><td>10</td><td>9</td><td>-</td><td>③</td></tr><tr><td>F</td><td>10</td><td>5</td><td>8</td><td>④</td><td>3</td><td>-</td></tr></table> Arcs in order: AC, CD, DB, DF, FE Weight: 13 (km) 		A	B	C	D	E	F	A	-	5	3	5	8	10	B	5	-	6	②	7	5	C	③	6	-	1	10	8	D	5	2	①	-	9	4	E	8	7	10	9	-	③	F	10	5	8	④	3	-	M1	1.1	5 entries ringed At most one ringed entry in each row
	A	B	C	D	E	F																																																
A	-	5	3	5	8	10																																																
B	5	-	6	②	7	5																																																
C	③	6	-	1	10	8																																																
D	5	2	①	-	9	4																																																
E	8	7	10	9	-	③																																																
F	10	5	8	④	3	-																																																
			A1	1.1	These arcs in this order, stated (not vertices and not just implied from labelling on table)																																																	
			B1	1.1	13 May see calculation leading to answer 13																																																	
			B1	1.1	Correct spanning tree drawn May include weights																																																	
			[4]																																																			

Question			Answer	Marks	AO	Guidance
3	(b)		eg How many different walks are there from A to F?	B1 [1]	1.1	Any question about counting number of walks from A to F Allow asking how many routes/paths/trails between any 2 vertices, may have restrictions (eg without repeating a vertex, or with a length restriction), allow listing them but must be an enumeration question not eg optimisation Allow 'how many ways are there to get from A to F'
3	(c)		A 1 0 B 4 5 F 5 8 C 2 3 E D 3 4 8 5 4 Path: A C D F Length: 8 km	M1 M1 A1 B1 [4]	1.1 2.5 1.1 2.2a	Evidence of Dijkstra's algorithm being used Stated or implied eg by boxes with correct structure Temporary labels 5 and 4 at D Allow temporary label 4 implied if seen as permanent at D Order and permanent distance all correct with E blank Ignore any extra temporary labels May have permanent distance 8 at E with order 6, or with order 5 at E and 6 at F, accept 5= A C D F (oe) and 8
			Alternative method A 6 8 B 4 5 F 1 0 C 5 5 E 2 3 D 3 4 10 9 8 8 5 Path: A C D F Length: 8 km	M1 M1 A1 B1		Starting from F Evidence of Dijkstra's algorithm being used Stated or implied eg by boxes with correct structure Temporary labels 8 and 5 at C Allow temporary label 5 implied if seen as permanent at C Order and permanent distance all correct Ignore any extra temporary labels Allow order 4 at C and 5 at B, accept 4= (order 5 or 6 at A) A C D F (oe) and 8

Question			Answer	Marks	AO	Guidance
4	(a)		Sum of corresponding entries is 6 so subtract 3 from each entry (for Ryan)	B1 [1]	2.2a	State that totals are always the same (6 if given) and describe how to obtain the given (zero-sum) values eg each total is 6, 3 minus each entry for Casey eg $R + C = 6$ for each cell, $\frac{1}{2}(R - C)$ Need some indication of ‘each cell’ common total and appropriate calculation, may imply Ryan
	(b)		X	B1 [1]	1.1	X, allow “first column” oe
	(c)		Worst outcomes for rows or columns seen Max (row min) or ($\pm$) min (col max) found correctly Play-safe for Ryan is B and for Casey both Y and Z are play-safes	M1 A1 B1 [3]	1.1 1.1 1.1	Rows: -2, 0, -2 Columns: 2, 1, 1 (or -2, -1, -1) At least one complete set of values Stated or indicated (may be implied from correct play-safe choice(s) for either player provided M1 achieved) B, Y, Z all stated as play-safes (or on answer line) with no others
	(d)		$0 \neq 1$ so game is not stable	B1 FT [1]	2.2a	Values of their play-safes compared and appropriate conclusion, FT their play-safes from (c) Row maximin $\neq$ col minimax so not stable Or ‘value chasing’ leading to not stable Or explanation of what is meant by a stable/unstable game and appropriate conclusion reached oe
	(e)		Row B (strictly) dominates row C as $2 > 0$, $0 > -2$, $1 > 0$ (so Ryan would never play option C)	B1 [1]	2.3	Must clearly show or explain why row B dominates row C, by comparing in each column (not just stating that B dominates C) not just writing out reduced table

Question		Answer	Marks	AO	Guidance
4	(f)	Expected pay-offs for Ryan are: $(-2)p + (2)(1 - p) = 2 - 4p \quad (\text{Casey plays X})$ $(1)p + (0)(1 - p) = p \quad (\text{Casey plays Y})$ $(0)p + (1)(1 - p) = 1 - p \quad (\text{Casey plays Z})$  Optimal pay-off for Ryan occurs when $p = 2 - 4p$ $p = 0.4$, so Ryan should randomly choose between options A and B, playing option A 2/5 of the time (and option B 3/5 of the time, never choose option C)	M1 A1 FT M1 A1 FT [4]	3.1a 1.1 3.4 3.2a	FT from 2×3 reduced table from (e), provided row A was not removed (and is chosen with probability p) Use values from (their) reduced zero-sum game Allow use of values from a reduced original table One expression (may be unsimplified) soi All three expressions seen May be implied from appropriate lines on scaled graph ISW errors in simplifying unless unsimplified not seen M0 if no graph drawn Sketch graph and identify where optimum occurs A plausible (sketch) graph, with three appropriate lines, FT their expressions Scales and labels may be implied if expressions seen algebraically and lines are consistent with these Check values when $p = 0, 1$, if possible Condone graphs that extend beyond $p = 1$ FT their expressions May be indicated on graph or implied from p value if no other working after the graph Interpret their value of p in the context of the game (value from their expressions and $0 < p < 1$) eg play A with probability 0.4 (B implied if not seen) but not just eg play A = 0.4, B = 0.6

Question			Answer	Marks	AO	Guidance																																																																																										
5	(a)		Semi-Eulerian as A and F are the <u>only</u> nodes with an odd order	B1 [1]	1.2	Accept semi-Eulerian because <u>exactly</u> two odd nodes Accept semi-Eulerian because 2 odd degree vertices and the rest are even																																																																																										
	(b)		eg ABCA	B1 [1]	1.1	Any valid cycle on graph <i>X</i> (connected, no repeated arcs, no repeated nodes, finishes at start node)																																																																																										
5	(c)		Graph <i>X</i> has two nodes of degree 2 (G and D) which are not connected by a direct arc Graph <i>Y</i> has two nodes of degree 2 (N and O) which are connected by a direct arc N and O are directly connected but D and G are not (So not isomorphic)	M1 M1 A1 [3]	3.1a 1.1 2.1	Identifying nodes with degree 2 in graph <i>X</i> and describing connections appropriately oe Identifying nodes with degree 2 in graph <i>Y</i> and describing connections appropriately oe Explaining that the connections between the identified nodes are different (dependent on both M marks) May be implied from eg <i>X</i> has ... but ... <i>Y</i> has ...																																																																																										
			For reference: Graph <i>X</i> 			For reference: Graph <i>Y</i> <table><tr><th></th><th>I</th><th>J</th><th>K</th><th>L</th><th>M</th><th>N</th><th>O</th><th>P</th><th>degree</th></tr><tr><th>I</th><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>4</td></tr><tr><th>J</th><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>4</td></tr><tr><th>K</th><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>3</td></tr><tr><th>L</th><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>4</td></tr><tr><th>M</th><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>3</td></tr><tr><th>N</th><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>2</td></tr><tr><th>O</th><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>2</td></tr><tr><th>P</th><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>4</td></tr></table>		I	J	K	L	M	N	O	P	degree	I	0	1	1	1	0	0	0	1	4	J	1	0	1	1	1	0	0	0	4	K	1	1	0	1	0	0	0	0	3	L	1	1	1	0	1	0	0	0	4	M	0	1	0	1	0	0	0	1	3	N	0	0	0	0	0	0	1	1	2	O	0	0	0	0	0	1	0	1	2	P	1	0	0	0	1	1	1	0	4
	I	J	K	L	M	N	O	P	degree																																																																																							
I	0	1	1	1	0	0	0	1	4																																																																																							
J	1	0	1	1	1	0	0	0	4																																																																																							
K	1	1	0	1	0	0	0	0	3																																																																																							
L	1	1	1	0	1	0	0	0	4																																																																																							
M	0	1	0	1	0	0	0	1	3																																																																																							
N	0	0	0	0	0	0	1	1	2																																																																																							
O	0	0	0	0	0	1	0	1	2																																																																																							
P	1	0	0	0	1	1	1	0	4																																																																																							

Question			Answer	Marks	AO	Guidance																								
6	(a)		Activity-on-Arrow (AOA) network diagram showing activities A, B, C, D, E, F, and G. The diagram includes event times (Early Event Time (EET) and Late Event Time (LET)) for each node. The activities and their durations are: A(3), B(1), C(2), D(2), E(5), F(2), and G(4). The network structure is as follows: Node 0 (Start) connects to Node 1 (via A) and Node 2 (via B). Node 1 connects to Node 3 (via C) and Node 2 (via dummy). Node 2 connects to Node 4 (via D). Node 3 connects to Node 5 (via E) and Node 4 (via dummy). Node 4 connects to Node 5 (via F). Node 5 connects to Node 6 (Finish) via G.	B1 M1 A1 [3]	3.1a 1.1 1.1	Activity on arc (durations need not be shown) No marks for activity on node Events need not be labelled, may have different labels Activities A, C, E, G form a path from start to end Condone directions missing, but not wrong directions Activities B, D, F, G form a path from start to end Condone directions missing, but not wrong directions Exactly two dummies used correctly (with no extras) All arcs directed appropriately, single start and finish																								
6	(b)	(i)	Evidence of forward pass used Evidence of backward pass used All event times correct, including start and finish <table><tr><td>Event</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr><tr><td>EET</td><td>0</td><td>3</td><td>3</td><td>5</td><td>5</td><td>10</td><td>14</td></tr><tr><td>LET</td><td>0</td><td>3</td><td>6</td><td>5</td><td>8</td><td>10</td><td>14</td></tr></table>	Event	0	1	2	3	4	5	6	EET	0	3	3	5	5	10	14	LET	0	3	6	5	8	10	14	M1 M1 A1 [3]	1.1 1.1 1.1	At least three correct early event times on diagram oe At least three correct late event times on diagram oe No FT from an activity network with incorrect precedences but allow FT if structure is correct but there are extra dummies that do not affect the precedences
Event	0	1	2	3	4	5	6																							
EET	0	3	3	5	5	10	14																							
LET	0	3	6	5	8	10	14																							
6	(b)	(ii)	Critical activities A, C, E, G (in any order)	B1 [1]	1.1	{A, C, E, G} and no others																								

Question			Answer	Marks	AO	Guidance
6	(c)		F had a float of 3 (hours)	M1	3.3	Calculating the float at F (may see $10 - 5 - 2$ oe) May imply F but must have 'float' and '3'
			So a delay of 4 hours (from 2 to 6) will add 1 hour to the completion time, taking it from 14 to 15 (hours)	A1 [2]	3.4	Explaining why the minimum project completion time increases by 1, or increases to 15
			Alternative method F becomes critical (instead of E) EET at event 5 = 11, EET at event 6 = 15	M1 A1		Critical activities are now A, C, D, F, G Allow 'it becomes critical' to mean F becomes critical 15 (hours) taken or time increased by 1 (hour)

Question			Answer	Marks	AO	Guidance
7	(a)		x = number of arrangement X (produced) y = number of arrangement Y (produced) z = number of arrangement Z (produced)	B1	1.1	Define variables representing the number of each type of arrangement eg x = number of X, $y = \dots$ Y, $z = \dots$ Z Other letters may be used but do not credit if different letters are used in objective and/or constraints and earn marks there May use ditto oe Must say ‘number of ...’ oe Using x, y, z or their variables (used consistently)
			Maximise $P = 20x + 15y + 24z$	B1	1.1	Max $20x + 15y + 24z$ oe
			Subject to $5x + 4y + 9z \leq 40$ (roses)	M1	3.3	One non-trivial constraint for flowers correct, oe
			$3x + 7y + 6z \leq 80$ (lilies) $5x + 2y + 7z \leq 30$ (carnations)	A1	1.1	All three non-trivial constraints for flowers correct, oe
			$y \leq x + z$ (number of Y) $x \geq 0, y \geq 0, z \geq 0$, and integer-valued	B1	3.1b	Correct formulation of constraint on number of Y (eg $y \leq 0.5(x + y + z)$ or $2y \leq x + y + z$ or $x - y + z \geq 0$ Allow omission of non-negativity and integer-valued Ignore any extra constraints Allow $<$ used instead of $\leq$ and $>$ used instead of $\geq$
				[5]		

Question			Answer	Marks	AO	Guidance
7	(b)	(i)	Non-trivial constraints become $14x + 4y \leq 40$ $9x + 7y \leq 80$ $12x + 2y \leq 30$ $y \leq 2x$	M1	3.5c	New constraints seen with z replaced by x (at least 2) Need not be simplified, allow = Condone one arithmetic slip Correct or FT their previous constraints
			M1	3.4	Correct boundary line drawn for at least one of their non-trivial constraints in x and y Axes should be scaled and labelled but condone if missing scales and/or labels are missing, may interchange axes throughout	
			A1	1.1	Line for roses passes through (1, 6.5) and (2, 3) Line for lilies is redundant (may be omitted) Line for carnations passes through (2, 3) and (2.5, 0) Line for number of Y passes through (0, 0) and (1, 2) Correct lines for roses, carnations and Y restrictions cao	
			A1	1.1	Feasible region correct shape Vertices at (0, 0), (2.5, 0), (2, 3) and approx. (1.8, 3.6)	
			M1	2.2a	Must give some evidence of method, even if feasible region is wrong (eg method stated; calculate P at 2 non-zero feasible points (integer-valued or vertices); equation of profit line rearranged as $y = \dots$; profit line(s) shown on diagram with gradient roughly -3) or implied from correct answer	
			A1	3.4	State (2, 3) or $x = 2, y = 3$ (and $z = 2$) cao	
				[6]		

Check coordinates or use a sliding profit line

x	1	1	1	1.8	2	2	2	2	2.5
y	0	1	2	3.6	0	1	2	3	0
P	44	59	74	134.5	88	103	118	133	110

$P = 44x + 15y$

Make 2 of type X, 3 of type Y (and 2 of type Z)

Question			Answer	Marks	AO	Guidance
7	(b)	(ii)	£133	B1 [1]	1.1	133 cao
7	(c)		$9x + 7y = k$ meets either $14x + 4y = 40$ or $12x + 2y = 30$ at (2, 3) $9(2) + 7(3) \leq k \Rightarrow k \geq 39$	M1 A1 [2]	2.4 1.1	Allow substituting (their) integer-valued (2, 3) into $9x + 7y = k$ and dealing with inequality $k \geq 39$ Allow $k > 39$ SC B1 if M0 scored but 39 seen in answer for k

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