2226 – 5225M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2026

Mathematics: applications and interpretation

Higher level

Paper 1

29 pages

Instructions to Examiners

Abbreviations

M Marks awarded for attempting to use a correct **Method**.

A Marks awarded for an **Answer** or for **Accuracy**; often dependent on preceding ***M*** marks.

R Marks awarded for clear **Reasoning**.

AG Answer given in the question and so no marks are awarded.

FT Follow through. The practice of awarding marks, despite candidate errors in previous parts, for their correct methods/answers using incorrect results.

Using the markscheme

1 General

Award marks using the annotations as noted in the markscheme *eg* ***M1, A2****.*

2 Method and Answer/Accuracy marks

- Do **not** automatically award full marks for a correct answer; all working **must** be checked, and marks awarded according to the markscheme.
- It is generally not possible to award ***M0*** followed by ***A1***, as ***A*** mark(s) depend on the preceding ***M*** mark(s), if any.
- Where ***M*** and ***A*** marks are noted on the same line, *e.g.* ***M1A1***, this usually means ***M1*** for an **attempt** to use an appropriate method (*e.g.* substitution into a formula) and ***A1*** for using the **correct** values.
- Where there are two or more ***A*** marks on the same line, they may be awarded independently; so if the first value is incorrect, but the next two are correct, award ***A0A1A1***.
- Where the markscheme specifies ***A3***, ***M2*** *etc.*, do **not** split the marks, unless there is a note.
- The response to a "show that" question does not need to restate the ***AG*** line, unless a **Note** makes this explicit in the markscheme.
- Once a correct answer to a question or part question is seen, ignore further working even if this working is incorrect and/or suggests a misunderstanding of the question. This will encourage a uniform approach to marking, with less examiner discretion. Although some candidates may be advantaged for that specific question item, it is likely that these candidates will lose marks elsewhere too.
- An exception to the previous rule is when an incorrect answer from further working is used **in a subsequent part**. For example, when a correct exact value is followed by an incorrect decimal approximation in the first part and this approximation is then used in the second part. In this situation, award ***FT*** marks as appropriate but do not award the final ***A1*** in the first part.

Examples:

	Correct answer seen	Further working seen	Any FT issues?	Action
1.	$8\sqrt{2}$	5.65685... *(incorrect decimal value)*	No. Last part in question.	Award ***A1*** for the final mark *(condone the incorrect further working)*
2.	$\frac{35}{72}$	0.468111… (incorrect decimal value)	Yes. Value is used in subsequent parts.	Award ***A0*** for the final mark *(and full **FT** is available in subsequent parts)*

3 Implied marks

Implied marks appear in **brackets e.g. *(M1)***,and can only be awarded if **correct** work is seen or implied by subsequent working/answer.

4 Follow through marks (only applied after an error is made)

Follow through (***FT***) marks are awarded where an incorrect answer from one **part** of a question is used correctly in **subsequent** part(s) (e.g. incorrect value from part (a) used in part (d) or incorrect value from part (c)(i) used in part (c)(ii)). Usually, to award ***FT*** marks, **there must be working present** and not just a final answer based on an incorrect answer to a previous part. However, if all the marks awarded in a subsequent part are for the answer or are implied, then ***FT*** marks should be awarded for *their* correct answer, even when working is not present.

For example: following an incorrect answer to part (a) that is used in subsequent parts, where the markscheme for the subsequent part is ***(M1)A1***, it is possible to award full marks for *their* correct answer, **without working being seen.** For longer questions where all but the answer marks are implied this rule applies but may be overwritten by a **Note** in the Markscheme.

- Within a question part, once an **error** is made, no further ***A*** marks can be awarded for work which uses the error, but ***M*** marks may be awarded if appropriate.

- If the question becomes much simpler because of an error then use discretion to award fewer ***FT*** marks, by reflecting on what each mark is for and how that maps to the simplified version.

- If the error leads to an inappropriate value (*e.g.* probability greater than 1, $\sin\theta = 1.5$, non-integer value where integer required), do not award the mark(s) for the final answer(s).

- The markscheme may use the word “their” in a description, to indicate that candidates may be using an incorrect value.

- If the candidate’s answer to the initial question clearly contradicts information given in the question, it is not appropriate to award any ***FT*** marks in the subsequent parts. This includes when candidates fail to complete a “show that” question correctly, and then in subsequent parts use their incorrect answer rather than the given value.

- Exceptions to these ***FT*** rules will be explicitly noted on the markscheme.

- If a candidate makes an error in one part but gets the correct answer(s) to subsequent part(s), award marks as appropriate, unless the command term was "Hence".

5 Mis-read

If a candidate incorrectly copies values or information from the question, this is a mis-read (***MR***). A candidate should be penalized only once for a particular misread. Use the ***MR*** stamp to indicate that this has been a misread and do not award the first mark, even if this is an ***M*** mark, but award all others as appropriate.

- If the question becomes much simpler because of the ***MR***, then use discretion to award fewer marks.

- If the ***MR*** leads to an inappropriate value (*e.g.* probability greater than 1, $\sin\theta = 1.5$, non-integer value where integer required), do not award the mark(s) for the final answer(s).

- Miscopying of candidates' own work does **not** constitute a misread, it is an error.

- If a candidate uses a correct answer, to a "show that" question, to a higher degree of accuracy than given in the question, this is NOT a misread and full marks may be scored in the subsequent part.

- ***MR*** can only be applied when work is seen. For calculator questions with no working and incorrect answers, examiners should **not** infer that values were read incorrectly.

6 Alternative methods

Candidates will sometimes use methods other than those in the markscheme. Unless the question specifies a method, other correct methods should be marked in line with the markscheme. If the command term is 'Hence' and not 'Hence or otherwise' then alternative methods are not permitted unless covered by a note in the mark scheme.

- Alternative methods for complete questions are indicated by **METHOD 1**, **METHOD 2**, *etc*.
- Alternative solutions for parts of questions are indicated by **EITHER** . . . **OR**.

7 Alternative forms

Unless the question specifies otherwise, **accept** equivalent forms.

- As this is an international examination, accept all alternative forms of **notation** for example 1.9 and 1,9 or 1000 and 1,000 and 1.000.

- Do not accept final answers written using calculator notation. However, ***M*** marks and intermediate ***A*** marks can be scored, when presented using calculator notation, provided the evidence clearly reflects the demand of the mark.

- In the markscheme, equivalent **numerical** and **algebraic** forms will generally be written in brackets immediately following the answer.

- In the markscheme, some **equivalent** answers will generally appear in brackets. Not all equivalent notations/answers/methods will be presented in the markscheme and examiners are asked to apply appropriate discretion to judge if the candidate work is equivalent.

8 Format and accuracy of answers

If the level of accuracy is specified in the question, a mark will be linked to giving the answer to the required accuracy. If the level of accuracy is not stated in the question, the general rule applies to final answers: *unless otherwise stated in the question all numerical answers must be given exactly or correct to three significant figures.*

Where values are used in subsequent parts, the markscheme will generally use the exact value, however candidates may also use the correct answer to 3 sf in subsequent parts. The markscheme will often explicitly include the subsequent values that come "*from the use of 3 sf values*".

Simplification of final answers: Candidates are advised to give final answers using good mathematical form. In general, for an ***A*** mark to be awarded, arithmetic should be completed, and any values that lead to integers should be simplified; for example, $\sqrt{\frac{25}{4}}$ should be written as $\frac{5}{2}$. An exception to this is simplifying fractions, where lowest form is not required (although the numerator and the denominator must be integers); for example, $\frac{10}{4}$ may be left in this form or written as $\frac{5}{2}$. However, $\frac{10}{5}$ should be written as 2, as it simplifies to an integer.

Algebraic expressions should be simplified by completing any operations such as addition and multiplication, e.g. $4e^{2x} \times e^{3x}$ should be simplified to $4e^{5x}$, and $4e^{2x} \times e^{3x} - e^{4x} \times e^{x}$ should be simplified to $3e^{5x}$. Unless specified in the question, expressions do not need to be factorized, nor do factorized expressions need to be expanded, so $x(x+1)$ and $x^2 + x$ are both acceptable.

Please note: intermediate ***A*** marks do NOT need to be simplified.

9 Calculators

A GDC is required for this paper, but if you see work that suggests a candidate has used any calculator not approved for IB DP examinations (eg CAS enabled devices), please follow the procedures for malpractice.

10. Presentation of candidate work

Crossed out work: If a candidate has drawn a line through work on their examination script, or in some other way crossed out their work, do not award any marks for that work unless an explicit note from the candidate indicates that they would like the work to be marked.

More than one solution: Where a candidate offers two or more different answers to the same question, an examiner should only mark the first response unless the candidate indicates otherwise. If the layout of the responses makes it difficult to judge, examiners should apply appropriate discretion to judge which is "first".

1. (a) recognition of binomial distribution (i.e. $X \sim \mathrm{B}(12, 0.73)$ where X is the number of heads) ***(M1)***

$0.212 (0.212150...)$ ***A1***

[2 marks]

(b) **METHOD 1**

recognition of cumulative binomial distribution ***(M1)***

$\mathrm{P}(X \geq 7)$ OR $1 - \mathrm{P}(X \leq 6)$ OR $\mathrm{P}(X > 6)$

$0.924 (0.923951...)$ ***A1***

METHOD 2

recognition of cumulative binomial distribution (i.e. $T \sim \mathrm{B}(12, 0.27)$) ***(M1)***

where T represents the number of tails

$\mathrm{P}(T \leq 5)$

$0.924 (0.923951...)$ ***A1***

[2 marks]

(c) attempt to find expected value using their (b) multiplied by 49 ***(M1)***

$45.3 (45.2736...)$ ***A1***

Note: Accept 45.

[2 marks]

Total [6 marks]

2 (a) **METHOD 1**

splitting up garden into two rectangles ***(M1)***

$A = 6x(x+4) + 2x(x+6)$ OR $A = (6x^2 + 24x) + (2x^2 + 12x)$ ***A1A1***

Note: Award ***A1*** for each correct term.

$A = 8x^2 + 36x$ ***AG***

METHOD 2

splitting up garden into two rectangles ***(M1)***

$A = 2x(2x+10) + 4x(x+4)$ OR $A = (4x^2 + 20x) + (4x^2 + 16x)$ ***A1A1***

Note: Award ***A1*** for each correct term.

$A = 8x^2 + 36x$ ***AG***

METHOD 3

subtracting two rectangles ***(M1)***

$A = 6x(2x+10) - 4x(x+6)$ OR $A = (12x^2 + 60x) - (4x^2 + 24x)$ ***A1A1***

Note: Award ***A1*** for each correct term.

$A = 8x^2 + 36x$ ***AG***

[3 marks]

(b) attempt to solve $8x^2 + 36x = 72$ OR $8x^2 + 36x - 72 = 0$ ***(M1)***

$x = 1.5$ ($x = -6$ is rejected) ***A1***

Note: Award ***(M1)A0*** if $x = -6$ is also given as a solution.

[2 marks]

(c) attempt to add the four sides $x+4, 6x, 2x+10$ and $2x$ with or without substituting their value for x ***(M1)***

fencing needed $= 11(1.5) + 14$ OR $5.5 + 9 + 13 + 3$

30.5 m ***A1***

[2 marks]

Total [7 marks]

3 (a) (i) $P'(5) = 0$ ***A1***

(ii) no growth (in the population of grasshoppers) ***A1***

OR

the population (of grasshoppers) has reached its maximum ***A1***

OR

the population (of grasshoppers) is in equilibrium

(since it is neither increasing nor decreasing) ***A1***

OR

the growth rate is zero ***A1***

OR

the rate of change of the population (of grasshoppers) is zero ***A1***

[2 marks]

(b) attempt to integrate the function (i.e. at least two correct terms) ***(M1)***

$P(t) = 70t + \frac{t^2}{2} - t^3 (+c)$ ***A1***

attempt to find the value of c (i.e. setting *their* $P(t) = 254$) ***(M1)***

$P(t) = 70t + \frac{t^2}{2} - t^3 + 16.5$ ***A1***

[4 marks]

(c) setting their $P(t) = 0$ ***(M1)***

$t = 8.73246...$

8.73 weeks ***A1***

Note: Award ***(M1)A0*** for an unsupported answer of 9 weeks.
Award ***(M1)A0*** for a final answer $-7.99615...$ or $-0.23630\ldots$ seen

[2 marks]

Total [8 marks]

4 (a)

	Lost	Not lost	Totals
Heavy	2	22	24
Not heavy	3	53	56
Totals	5	75	80

A2

Note: Award ***A1*** for one row or column correct (as well as the totals row), ***A2*** for completely correct.

[2 marks]

(b) (i) $\frac{56}{80}\left(\frac{7}{10}, 0.7\right)$ ***A1***

(ii) $\frac{2}{24}\left(\frac{1}{12}, 0.0833333...\right)$ ***A1***

[2 marks]

(c) let X be the weight of the bag

$\mathrm{P}(\text{Heavy}) = \mathrm{P}(X > 18) = 0.252 (0.252492...)$ ***A1***

attempt to multiply two probabilities, one of which must be their $\mathrm{P}(X > 18)$ ***M1***

$\mathrm{P}(\text{Heavy and lost}) = = 0.252492... \times \frac{1}{12}$

$= 0.0210 \ (0.0210410...)$ ***A1***

[3 marks]

Total [7 marks]

5 (a) BC or CE or ED ***A1***

[1 mark]

(b) (i) No, it is not possible to go from E to B ***A1R1***

OR

No, because there is a 0 in M^3 ***A1R1***

Note: Award ***A1R0*** for 'No, it is not possible to go from B to E '. Otherwise do not award ***A1R0.***

(ii) Yes, because E to B can be done in two transitions ***A1R1***

(or in less than three transitions)

OR

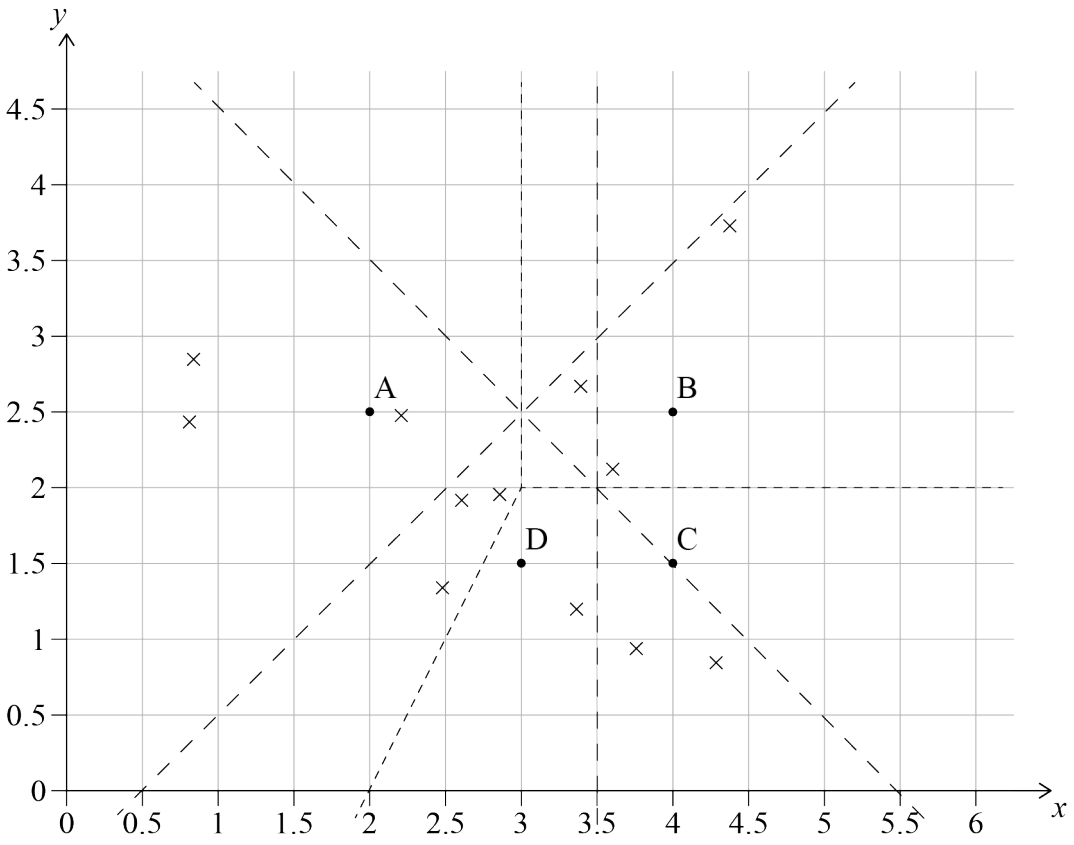
Yes, because there are no zero entries in $M^2 + M^3$ ' or equivalent. ***A1R1***

Note: Do not award ***A1R0.*** Condone 'because B to E can be done in two transitions'.

[4 marks]

Total [5 marks]

6 (a)



A1 for perpendicular bisector of [DC].

A1 for perpendicular bisector of [AD], passing through $(0.5,\ 0)$ and $(2.5,\ 2)$.

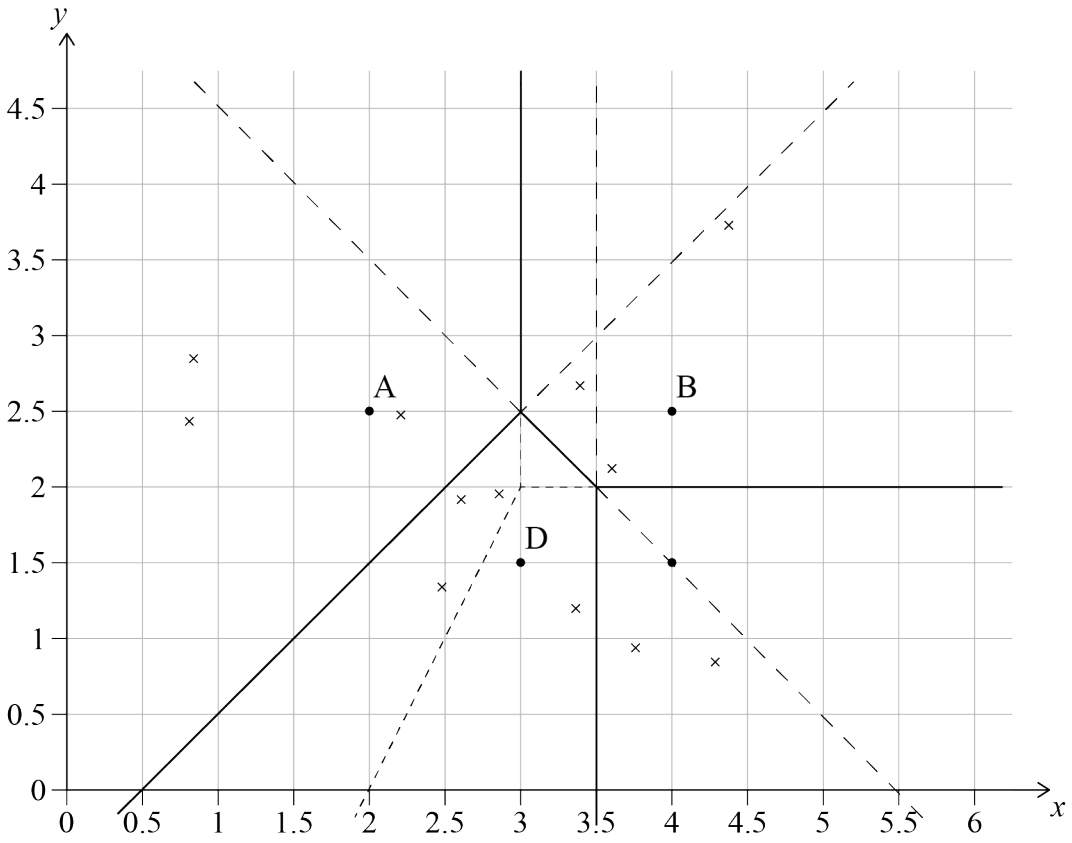
A1 for perpendicular bisector of [BD], passing through $(5.5,\ 0)$ and $(3.5,\ 2)$.

[3 marks]

continued…

Question 6 continued

(b)



attempt at defining appropriate regions with at least two edges ***M1***

all edges correct sufficiently long to define the region ***A1***

[2 marks]

(c) Hotel D (which is closest to 4 of the attractions) ***A1***

[1 mark]

Total [6 marks]

7 (a) let the angle between the vectors = θ

EITHER

attempt to find the scalar product (***M1)***

$\boldsymbol{F} \bullet \boldsymbol{r} = 9 - 3 + 0$

$= 6$ ***(A1)***

$\cos\theta = \dfrac{6}{\sqrt{18}\sqrt{14}} \left(= \dfrac{1}{\sqrt{7}} = \dfrac{\sqrt{7}}{7} \right)$ (***A1)***

Note: Follow through for the (***A1)*** using their value for the scalar product.

OR

attempt to find the vector product (***M1)***

$\boldsymbol{r} \times \boldsymbol{F} = \begin{pmatrix} 6 \\ -6 \\ -12 \end{pmatrix}$ ***(A1)***

$\sin\theta = \dfrac{\sqrt{6^2 + (-6)^2 + (-12)^2}}{\sqrt{18}\sqrt{14}} \left(= \dfrac{\sqrt{42}}{7} \right)$ (***A1)***

Note: Follow through for the (***A1)*** using their value for the vector product.

THEN

67.8° $(67.7923...)$ OR 1.18 $(1.18319...)$ ***A1***

[4 marks]

continued…

Question 7 continued

(b) **EITHER**

attempt to use vector product formula $|\boldsymbol{r} \times \boldsymbol{F}| = |\boldsymbol{r}|\,|\boldsymbol{F}| \sin\theta$ (***M1)***

$|\boldsymbol{T}| = \sqrt{18}\sqrt{14}\sin(67.7923...)$ ***(A1)***

OR

$\boldsymbol{r} \times \boldsymbol{F} = \begin{pmatrix} 6 \\ -6 \\ -12 \end{pmatrix}$ (***A1)***

Note: Working for vector product could be seen in part (a).

finding the magnitude of their cross product (***M1)***

$|\boldsymbol{T}| = \sqrt{6^2 + (-6)^2 + (-12)^2}$

THEN

$14.7\ \left(14.6969...,\ 6\sqrt{6},\ \sqrt{216}\right)$ ***A1***

[3 marks]

Total [7 marks]

8 (a) (i) $0.811\ (0.810584...)$ ***A1***

(ii) mean of $2.1\ \left(X \sim \text{Po}(2.1)\right)$ ***A1***

$\text{P}(X \leq 2) = 0.650\ (0.649631...)$ ***A1***

Note: Accept 0.65.

[3 marks]

(b) (i) attempt to find $\text{E}(C)$ using $C = 12X + 5$ ***(M1)***

$\text{E}(C) = 12 \times 2.1 + 5$

30.2 or 30.20 dollars ***A1***

(ii) attempt to find $\text{Var}(C)$ using $\text{Var}(X) = 2.1$ OR $\text{Var}(C) = 12^2 \times \text{Var}(X)$ ***(M1)***

144×2.1

302.4 or 302.40 dollars ***A1***

[4 marks]

(c) any valid reason, for example,

'mean does not equal variance' ***R1***

OR

'not all positive integers are in the sample space for C' ***R1***

[1 mark]

Total [8 marks]

9 (a) (i) attempt to find the characteristic quadratic ***(M1)***

$(1-\lambda)(4-\lambda)-10=0$ ***(A1)***

$\lambda^2-5\lambda-6=0$

$\lambda=6\ (\lambda=-1)$ ***A1***

(ii) setting up a correct equation to find eigenvector ***(M1)***

$$\begin{pmatrix}1-6 & 2\\ 5 & 4-6\end{pmatrix}\begin{pmatrix}x\\ y\end{pmatrix}=\begin{pmatrix}0\\ 0\end{pmatrix}$$

eigenvector corresponding to $\lambda=6$ is $\begin{pmatrix}2\\ 5\end{pmatrix}$ ***A1***

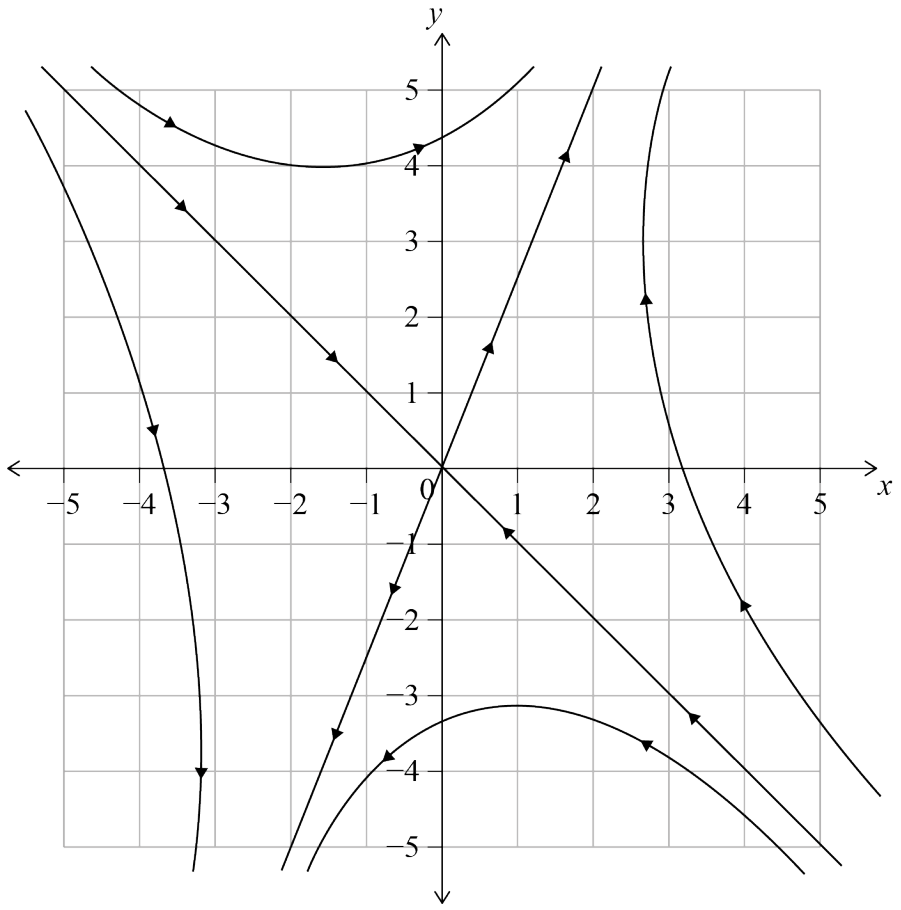
Note: Accept any scalar multiple of $\begin{pmatrix}2\\ 5\end{pmatrix}$.

[5 marks]

continued…

Question 9 continued

(b)



A1A1A1

Note: Award ***A1*** for the lines $y = -x$ and $y = \frac{5}{2}x$ drawn correctly (arrows not needed to award this ***A1***), ***A1*** for correct arrows on their lines, ***A1*** for correct trajectory in each section.

[3 marks]

Total [8 marks]

10 (a) recognition that circumference equals arc length ***(M1)***

$x\theta = 18$ and $(x+10)\theta = 24$ ***(A1)***

Note: Award ***A1*** for correct equations using degrees (i.e. $\frac{\theta}{360} \times 2\pi x = 18$ and $\frac{\theta}{360} \times 2\pi(10+x) = 24$ or equivalent).

attempt to eliminate one variable from their equations in θ and x ***(M1)***

$10\theta = 6$ OR $\frac{18}{x} = \frac{24}{x+10}$

$\theta = 0.6$ radians, $x = 30$ cm ***A1A1***

Note: Do not award final ***A1*** if angle is given in degrees.

[5 marks]

(b) **EITHER**

use of area formula and subtraction of two areas ***(M1)***

$\frac{1}{2} \times 40^2 \times 0.6 - \frac{1}{2} \times 30^2 \times 0.6$

OR

multiplying the average of the arc lengths by the slant height ***(M1)***

$\frac{1}{2} \times (18+24) \times 10$

THEN

210 cm^2 ***A1***

[2 marks]

Total [7 marks]

11 (a) $y = 4 - x^2$

swapping variables (seen anywhere) ***(M1)***

$x = 4 - y^2$

$\left(f^{-1}(x) =\right)\sqrt{4-x},\ 0 \le x \le 4$ ***A1A1A1***

Note: Award ***A1*** for $\sqrt{4-x}$, ***A1*** for finding upper limit of 4, ***A1*** for the correct domain.

Note: Do not award ***A1*** for $\pm\sqrt{4-x}$ unless clear evidence is seen that the negative has been rejected.

[4 marks]

(b) attempt to use of volume formula for rotation about y-axis ***(M1)***

$\pi\int_0^4 (4-x)\,\mathrm{d}x$ or $\pi\int_0^4 (4-y)\,\mathrm{d}y$ ***(A1)***

Note: Accept $\pi\int_0^4 \left(\sqrt{4-x}\right)^2 \mathrm{d}x$ or $\pi\int_0^4 \left(\sqrt{4-y}\right)^2 \mathrm{d}y$

Note: Condone absence of $\mathrm{d}x$ (or $\mathrm{d}y$)

$25.1\left(25.1327\ldots, 8\pi\right)$ ***A1***

[3 marks]

Total [7 marks]

12 (a) (i) 1 ***A1***

(ii) $-x$ ***A1***

[2 marks]

(b) attempt to use the expectation formula ***(M1)***

$$\mathrm{E}(Y) = \frac{1+3+4+5+6-x}{6}\left(= \frac{19-x}{6}\right)$$ ***A1***

Note: Do not allow follow through if their value of b is not a function of x. ***M1*** can still be awarded for an attempt at using the expectation formula.

[2 marks]

(c) $x = 20$ ***A1***

[1 mark]

Total [5 marks]

13 (a) recognition that for particle to be travelling parallel to the y -axis $\dot{x} = 0$ ***(M1)***

$2\sin(3t) - 1 = 0$

$t = 0.175 \left(0.174532..., \frac{\pi}{18} \right)$ ***A1***

Note: Award ***(M1)A0*** for an answer of 10 from working in degrees.

[2 marks]

(b) attempt to integrate ***M1***

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} -\frac{2}{3}\cos(3t) - t\left(+c_1\right) \\ t^2\left(+c_2\right) \end{pmatrix}$$ ***A1***

Note: Award ***A1*** for at least one component correctly integrated. Condone the use of c for both constants of integration.

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} -\frac{2}{3}\cos(3t) - t + \frac{2}{3} \\ t^2 \end{pmatrix}$$ ***A1***

[3 marks]

Total [5 marks]

14 (a) recognition that at maximum $\frac{\mathrm{d}y}{\mathrm{d}x}=0$ ***M1***

$3\times(-0.5)^2+2y-6.75=0$ ***A1***

$y=3$ ***AG***

[2 marks]

(b) use of the Euler formula, (beginning at $(-0.5,3)$) ***(M1)***

Note: $x_{n+1}=x_n+0.1$ is insufficient to award the ***M1*** mark, an attempt to find y_{n+1} is required.

$y_{n+1}=y_n+0.1\left(3x_n^2+2y_n-6.75\right)$ ***(A1)***

Note: The ***A1*** is awarded independently of the ***M1.***

$=-0.240(-0.239616...)$ ***A1***

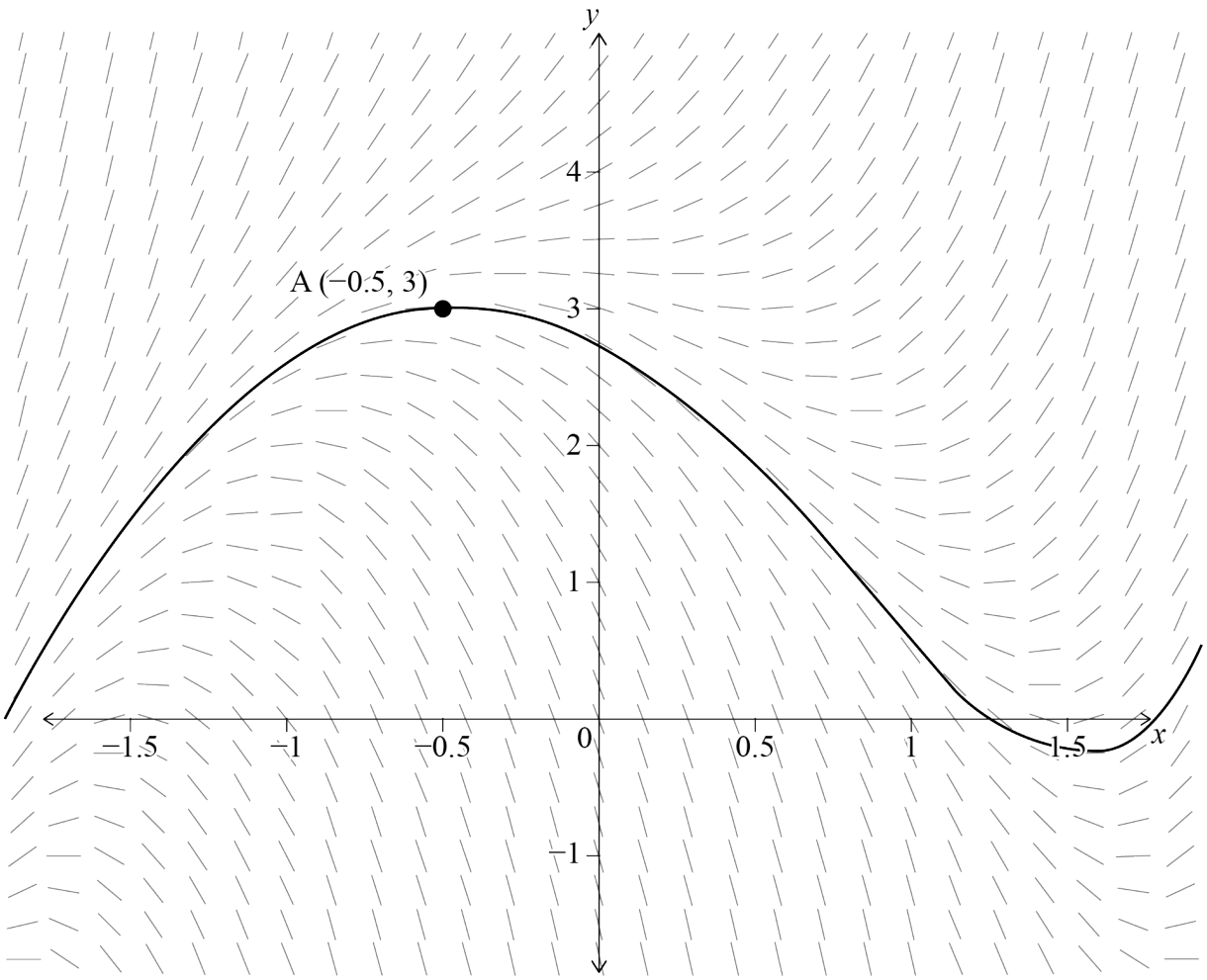
Note: Accept -0.24.

[3 marks]

continued…

Question 14 continued

(c)



A1

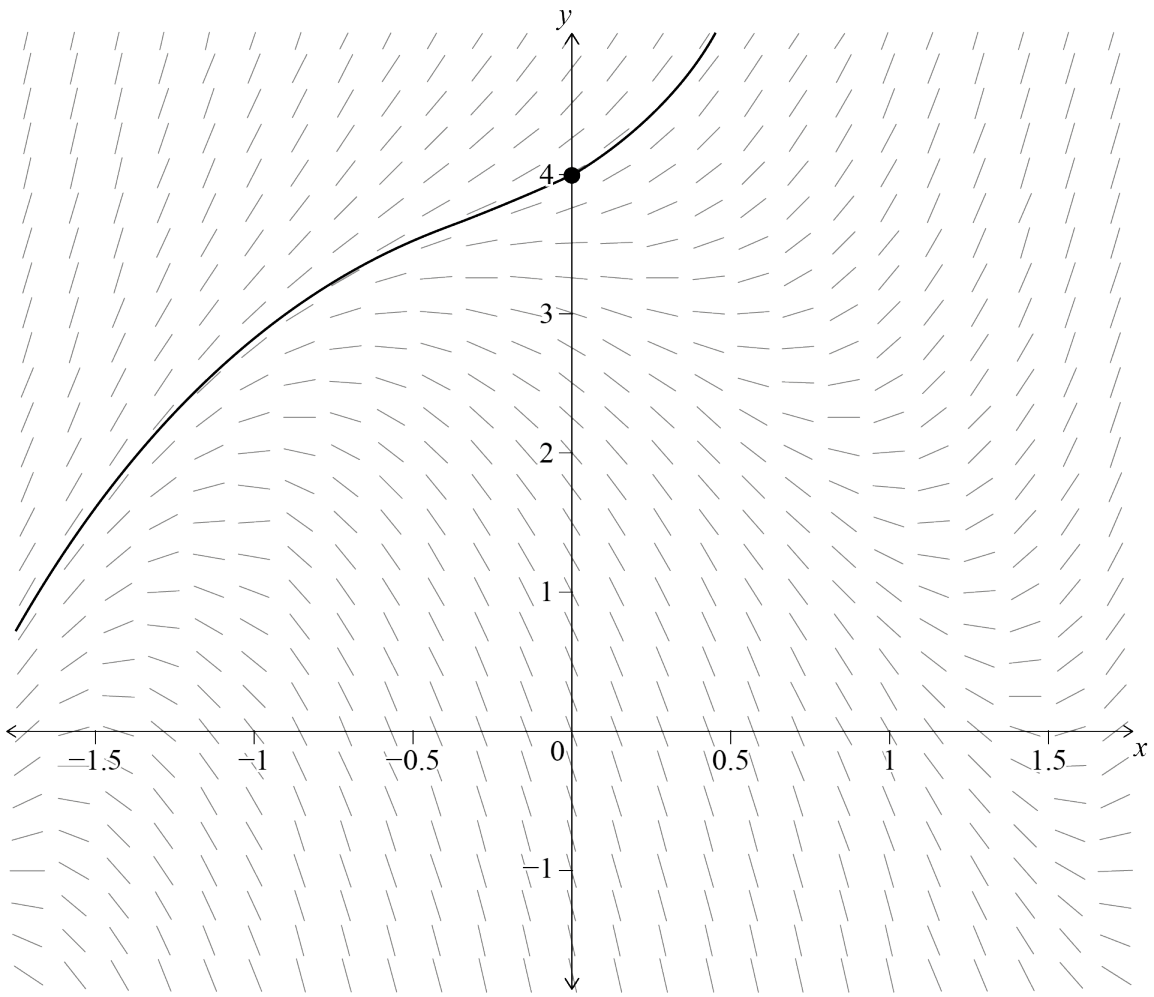
Award ***A1*** for curve with correct shape and approximately correct maximum point $(-0.5, 3)$ and minimum point (1.6, their value from (b)).

[1 mark]

continued…

Question 14 continued

(d)



A1A1

Award ***A1*** for solution curve passing through $(0,4)$, ***A1*** for general shape with no maximums or minimums

[2 marks]

Total [8 marks]

15 (a) (i) attempt at chain rule, product of x and $\left(4+x^2\right)^{-\frac{1}{2}}$ must be seen ***M1***

$$\frac{\mathrm{d}T}{\mathrm{d}x}=-2+10\times\frac{1}{2}\times 2x\left(4+x^2\right)^{-\frac{1}{2}}$$ ***A1A1***

Note: Award ***A1*** for -2 (independent of ***M1)*** , ***A1*** for correct second term of the expression.

$$\frac{\mathrm{d}T}{\mathrm{d}x}=-2+10x\left(4+x^2\right)^{-\frac{1}{2}}$$

(ii) use of a valid method to solve their equation ***(M1)***

$x=0.408\left(=\frac{\sqrt{6}}{6}=0.408248...\right)$ km ***A1***

[5 marks]

(b) **METHOD 1**

substitute $x=0.408$ or recognition that $\frac{\mathrm{d}^2T}{\mathrm{d}x^2}=\frac{40}{\left(4+x^2\right)^{\frac{3}{2}}}$ is always positive ***M1***

because the $\frac{\mathrm{d}^2T}{\mathrm{d}x^2}$ is positive the point is a minimum ***R1AG***

METHOD 2

graph of first derivative ***M1***

moves from negative to positive when $x=0.408$, hence a minimum ***R1AG***

METHOD 3

graph of original function for an arbitrary value of d ***M1***

statement that nature of point is independent of d ***R1***

[2 marks]

continued…

Question 15 continued

(c) substitution of their $x = 0.408$ into equation for T ***(M1)***

$L = 2\left(d - 0.408248...\right) + 10\sqrt{4 + 0.408248...^2}$

$L = 2d + 19.6 \ \left(L = 2d + 19.5959...\right)$ ***A1***

$\left(p = 2,\ q = 19.6\left(8\sqrt{6}\right)\right)$

[2 marks]

Total [9 marks]

16 (a) attempt to find $|6+2.5\mathrm{i}|$ ***(M1)***

6.5 ***A1***

[2 marks]

(b) $7.06\mathrm{e}^{0.833\mathrm{i}}$ $\left(7.06457...\mathrm{e}^{0.833093...\mathrm{i}}\right)$ ***A1A1***

Note: Award ***A1*** for 7.06 and ***A1*** for $0.833\mathrm{i}$.

[2 marks]

(c) **METHOD 1**

attempt to use cosine rule ***(M1)***

$$\cos \mathrm{A\hat{B}C} = \frac{6.5^2 + 7.06457...^2 - 3^2}{2 \times 6.5 \times 7.06457...}$$ ***(A1)***

0.438 $\left(0.438302..., 25.1128...^\circ\right)$ ***A1***

METHOD 2

$\mathrm{A\hat{C}B}$ $\left(= 2 - 0.833093...\right)$ $= 1.16690...$ ***(A1)***

attempt to use sine rule ***(M1)***

Note: The ***M1*** is conditional on the ***A1***.

$$\frac{\sin \mathrm{A\hat{B}C}}{3} = \frac{\sin\left(1.16690...\right)}{6.5}$$

0.438 $\left(0.438302..., 25.1128...^\circ\right)$ ***A1***

Note: Accept 0.439 if rounded values 7.06 and 0.833 are used.

[3 marks]

Total [7 marks]