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MARKSCHEME

November 2002

MATHEMATICAL METHODS

Standard Level

Paper 2

20 pages

Paper 2 Markscheme

Instructions to Examiners

1 Method of marking

(a) All marking must be done using a **red** pen.

(b) Marks should be noted on candidates' scripts as in the markscheme:

- show the breakdown of individual marks using the abbreviations *(M1)*, *(A2) etc*.

- write down each part mark total, indicated on the markscheme (for example, *[3 marks]*) – it is suggested that this be written at the end of each part, and underlined;

- write down and circle the total for each question at the end of the question.

2 Abbreviations

The markscheme may make use of the following abbreviations:

M Marks awarded for **Method**

A Marks awarded for an **Answer** or for **Accuracy**

G Marks awarded for correct solutions, generally obtained from a **Graphic Display Calculator**, irrespective of working shown

C Marks awarded for **Correct** statements

R Marks awarded for clear **Reasoning**

AG **Answer Given** in the question and consequently marks are **not** awarded

3 Follow Through (ft) Marks

Questions in this paper were constructed to enable a candidate to:

· show, step by step, what he or she knows and is able to do;

· use an answer obtained in one part of a question to obtain answers in the later parts of a question.

Thus errors made at any step of the solution can affect all working that follows. Furthermore, errors made early in the solution can affect more steps or parts of the solution than similar errors made later.

To limit the severity of the penalty for errors made at any step of a solution, **follow through (ft)** marks should be awarded. The procedures for awarding these marks require that all examiners:

(i) penalise an error when it **first occurs**;

(ii) **accept the incorrect answer** as the appropriate value or quantity to be used in all subsequent parts of the question;

(iii)   award *M* marks for a correct method, and *A*(ft) marks if the subsequent working contains no further errors.

Follow through procedures may be applied repeatedly throughout the same problem.

The errors made by a candidate may be: arithmetical errors; errors in algebraic manipulation; errors in geometrical representation; use of an incorrect formula; errors in conceptual understanding.

The following illustrates a use of the **follow through** procedure:

Markscheme		Candidate's Script	Marking	
$ 600 × 1.02	*M1*	Amount earned = $ 600 × 1.02	√	*M1*
= $ 612	*A1*	= $602	×	*A0*
$ (306 × 1.02) + (306 × 1.04)	*M1*	Amount = 301 × 1.02 + 301 × 1.04	√	*M1*
= $ 630.36	*A1*	= $ 620.06	√	*A1*(ft)

Note that the candidate made an arithmetical error at line 2; the candidate used a correct method at lines 3, 4; the candidate's working at lines 3, 4 is correct.

However, if a question is transformed by an error into a **different, much simpler question** then:

(i)   **fewer** marks should be awarded at the discretion of the Examiner;

(ii)   marks awarded should be followed by '**(d)**' (to indicate that these marks have been awarded at the **discretion** of the Examiner);

(iii)   a brief **note** should be written on the script explaining **how** these marks have been awarded.

4   Using the Markscheme

(a)   This markscheme presents a particular way in which each question may be worked and how it should be marked. **Alternative methods** have not always been included. Thus, if an answer is wrong then the working must be carefully analysed in order that marks are awarded for a different method in a manner which is consistent with the markscheme.

        In this case:

(i)   a mark should be awarded followed by '**(d)**' (to indicate that these marks have been awarded at the **discretion** of the Examiner);

(ii)   a brief **note** should be written on the script explaining **how** these marks have been awarded.

        Alternative solutions are indicated by **OR**. Where these are accompanied by *G* marks, they usually signify that the answer is acceptable from a graphic display calculator without showing working. For example:

        Mean = 7906/134   *(M1)*
             = 59   *(A1)*

        OR

        Mean = 59   *(G2)*

(b)   Unless the question specifies otherwise, accept **equivalent forms**. For example: $\frac{\sin\theta}{\cos\theta}$ for $\tan\theta$.
These equivalent numerical or algebraic forms may be written in brackets after the required answer.

(c)   As this is an international examination, all **alternative forms of notation** should be accepted. For example: 1.7 , 1·7 , 1,7 ; different forms of vector notation such as $\vec{u}$, $\overline{u}$, $\underline{u}$; $\tan^{-1} x$ for arctan x.

5   Accuracy of Answers

There are two types of accuracy errors, incorrect level of accuracy, and rounding errors. Unless the level of accuracy is specified in the question, candidates should be penalized **once only IN THE PAPER** for any accuracy error **(AP)**. This could be an incorrect level of accuracy, or a rounding error. Hence, on the **first** occasion in the paper when a correct answer is given to the wrong degree of accuracy, or rounded incorrectly, maximum marks are **not** awarded, but on **all subsequent occasions** when accuracy errors occur, then maximum marks **are** awarded.

There are also situations (particularly in some of the options) where giving an answer to more than 3 significant figures is acceptable. This will be noted in the markscheme.

(a)   **Level of accuracy**

   (i)   In the case when the accuracy of the answer is **specified in the question** (for example: "find the size of angle *A* to the nearest degree") the maximum mark is awarded **only if** the correct answer is given to the accuracy required.

   (ii)   When the accuracy is **not** specified in the question, then the general rule applies:

   Unless otherwise stated in the question, all numerical answers must be given exactly or to three significant figures.

(b)   **Rounding errors**

   Rounding errors should only be penalized at the **final answer** stage. This does **not** apply to intermediate answers, only those asked for as part of a question. Premature rounding which leads to incorrect answers should only be penalized at the answer stage.

Incorrect answers are wrong, and should not be considered under (a) or (b).

Examples

A question leads to the answer 4.6789….

*   4.68 is the correct 3 s.f. answer.

*   4.7, 4.679 are to the wrong level of accuracy, and should be penalised the first time this type of error occurs.

*   4.67 is incorrectly rounded – penalise on the first occurrence.

Note: All these "incorrect" answers may be assumed to come from 4.6789..., even if that value is not seen, but previous correct working is shown. However, 4.60 is wrong, as is 4.5, 4.8, and these should be penalised as being incorrect answers, not as examples of accuracy errors.

Markscheme		Candidate's Script (A)	Marking
(a) $a = 2.31 \times 3.43$	*M1*	(a) $a = 2.31 \times 3.43$	*M1*
$= 7.9233 = 7.92$ (3 s.f.)	*A1*	$= 7.9233 = 7.92$	*A1*
(b) $2a = 2 \times 7.9233$	*A1*	(b) $2a = 2 \times 7.29 = 14.58$	*A0*
$= 15.8466 = 15.8$ (3 s.f.)	*A1*	$= 14.5$	*A0*(**AP**)
		Total	*2 marks*

Notes: Award *A1* for either the exact answer 7.9233 or the 3 s.f. answer 7.92.

In line 3, Candidate A has incorrectly transcribed the answer for part (a), but then performs the calculation correctly, and would normally gain the follow through marks. However, the final answer is incorrectly rounded, and the **AP** applies.

Candidate's Script (B)	Marking		Candidate's Script (C)	Marking
(a) $a = 2.31 \times 3.43 = 7.9233$	*M1*		(a) $a = 2.31 \times 3.43 = 7.9233$	*M1*
$= 7.92$	*A1*		$= 7.93$	*A0*(**AP**)
(b) $2a = 2 \times 7.9233$	*A1*		(b) $2a = 2 \times 7.93$	*A1*(ft)
$= 15.8466 = 15.85$	*A0*(**AP**)		$= 15.86$ $= 15.8$	*A1*(ft)
Total	*3 marks*		Total	*3 marks*

Notes: Candidate B has given the answer to part (b) to the wrong level of accuracy, **AP** applies.

Candidate C has incorrectly rounded the answers to both parts (a) and (b), is penalised (**AP**) on the first occurrence (line 2), and awarded follow through marks for part (b).

Candidate's Script (D)	Marking		Candidate's Script (E)	Marking
(a) $a = 2.31 \times 3.43$	*M1*		(a) $a = 2.31 \times 3.43 = 7.923$	*M1*
$= 7.923 = 7.9$	*A0*(**AP**)		$= 7.93$	*A0*(**AP**)
(b) $2a = 2 \times 7.923$	*A1*(ft)		(b) $2a = 2 \times 7.93$	*A1*(ft)
$= 19.446 = 19.5$	*A0*		$= 15.86$	*A1*(ft)
Total	*2 marks*		Total	*3 marks*

Notes: Candidate D has given the answer to part (a) to the wrong level of accuracy, and therefore loses 1 mark (**AP**). The answer to part (b) is wrong.

Candidate E has incorrectly rounded the answer to part (a), therefore loses 1 mark (**AP**), is awarded follow through marks for part (b), and does **not** lose a mark for the wrong level of accuracy.

6   Graphic Display Calculators

Many candidates will be obtaining solutions directly from their calculators, often without showing any working. They have been advised that they must use mathematical notation, not calculator commands when explaining what they are doing. Incorrect answers without working will receive no marks. However, if there is written evidence of using a graphic display calculator correctly, method marks may be awarded. Where possible, examples will be provided to guide examiners in awarding these method marks.

1.   (a)
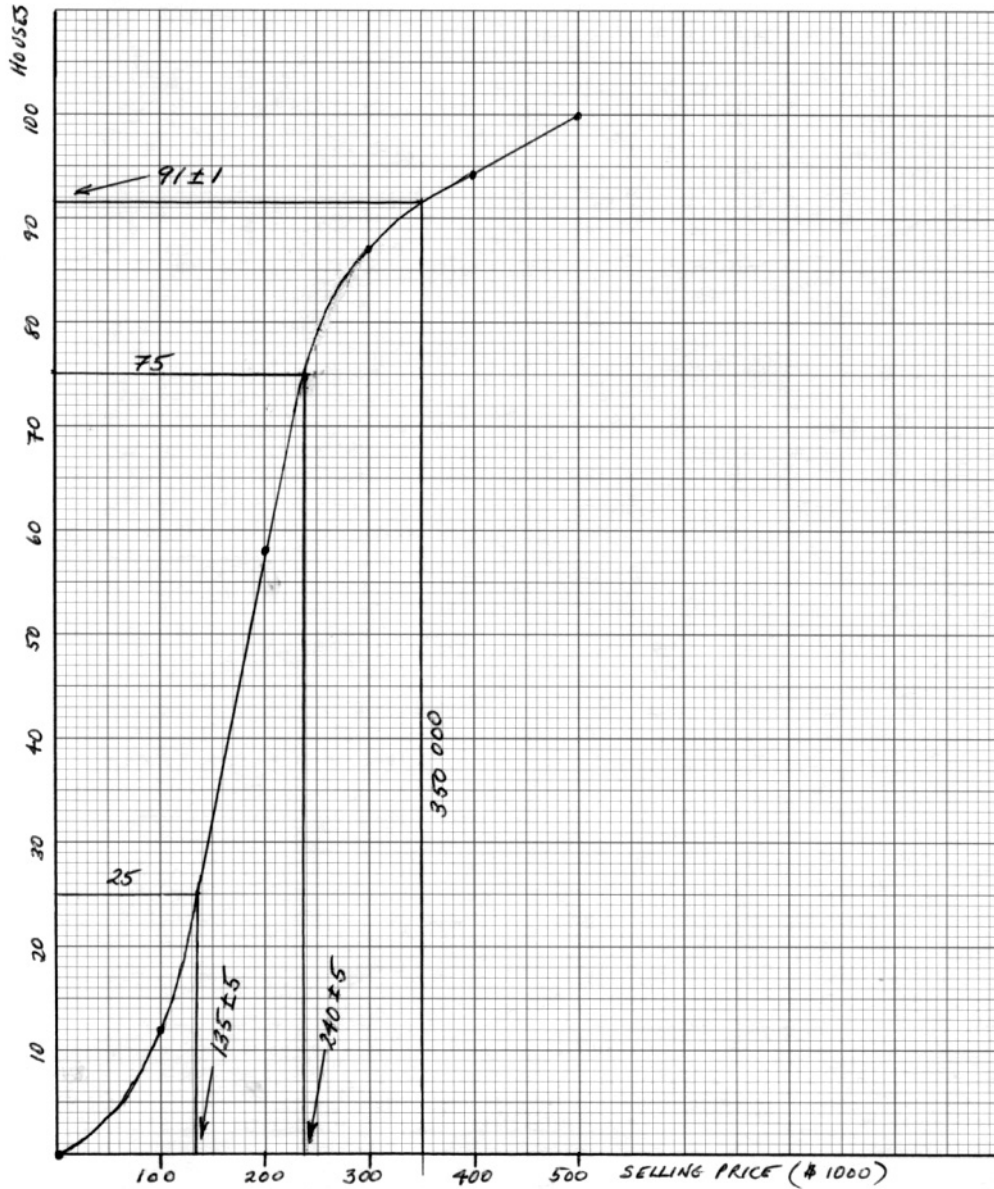
                                                                                      (A1)(A2)(A1)

> **Notes:** Award *(A1)* for correct axes, scales and labelling, *(A1)* for correctly plotted points.
>   Award *(A2)* for good curve correctly drawn, *(A1)* for badly drawn, correct curve.
>   Award *(A1)* for a correct polygon.

                                                                                      [4 marks]

(b) $Q_1 = 135 \pm 5$ $Q_3 = 240 \pm 5$ *(M1)(A1)*
       Interquartile range $= 105 \pm 10$. (Accept 135 – 240 or 240 – 135.)   *(A1)*

> **Note:**   Award *(M1)* for the correct lines on the graph.

                                                                                      [3 marks]

(c) $a = 94 - 87 = 7, b = 100 - 94 = 6$ *(A1)(A1)*

                                                                                      [2 marks]

                                                                                      continued…

Question 1 continued

(d)   mean $= \dfrac{12(50)+46(150)+29(250)+7(350)+6(450)}{100}$ *(M1)*

$\qquad = 199$ or $\$199\,000$ *(A1)*

OR

mean $= 199$ or $\$199\,000$ *(G2)*

[2 marks]

(e)   (i) $\$350\,000 \Rightarrow 91.5$

Number of *De luxe* houses $\simeq 100 - 91.5$ *(M1)*

$= 9$ or 8 *(A1)*

(ii) $\text{P (both} > 400\,000) = \dfrac{6}{9}\left(\dfrac{5}{8}\right)=\dfrac{5}{12}$ or $\dfrac{6}{8}\left(\dfrac{5}{7}\right)=\dfrac{15}{28}$ *(M1)(A1)*

Note: Award *(M1)(A0)* for the answers $\dfrac{4}{9}$ or $\dfrac{9}{16}$ obtained from correct independent probabilities.

[4 marks]

Total [15 marks]

2. (a) (i) $PQ = \sqrt{AP^2 + AQ^2}$ **(M1)**

$= \sqrt{2^2 + 2^2} = \sqrt{4(2)} = 2\sqrt{2}$ cm   **(A1)(AG)**

(ii)   Area of PQRS $= \left(2\sqrt{2}\right)\left(2\sqrt{2}\right) = 8$ cm^2 **(A1)**

[3 marks]

(b) (i)   Side of third square $= \sqrt{\left(\sqrt{2}\right)^2 + \left(\sqrt{2}\right)^2} = \sqrt{4} = 2$ cm

Area of third square $= 4$ cm^2 **(A1)**

(ii) $\dfrac{1^{st}}{2^{nd}} = \dfrac{16}{8} \quad \dfrac{2^{nd}}{3^{rd}} = \dfrac{8}{4}$ **(M1)**

$\Rightarrow$ Geometric progression, $r = \dfrac{8}{16} = \dfrac{4}{8} = \dfrac{1}{2}$ **(A1)**

[3 marks]

(c) (i) $u_{11} = u_1 r^{10} = 16\left(\dfrac{1}{2}\right)^{10} = \dfrac{16}{1024}$ **(M1)**

$= \dfrac{1}{64} \, (= 0.015625 = 0.0156, \text{3 s.f.})$ **(A1)**

(ii) $S_\infty = \dfrac{u_1}{1-r} = \dfrac{16}{1-\dfrac{1}{2}}$ **(M1)**

$= 32$ **(A1)**

[4 marks]

Total [10 marks]

3. (a)   At A, $x = 0 \;\Rightarrow\; y = \sin(e^0) = \sin(1)$ *(M1)*

   $\Rightarrow$ coordinates of A $= (0, 0.841)$ *(A1)*

   OR

   $A(0, 0.841)$ *(G2)*

                                                                              [2 marks]

   (b) $\sin(e^x) = 0 \;\Rightarrow\; e^x = \pi$ *(M1)*

   $\Rightarrow\; x = \ln \pi \,(\text{or } k = \pi)$ *(A1)*

   OR

   $x = \ln \pi \,(\text{or } k = \pi)$ *(A2)*

                                                                              [2 marks]

   (c)   (i)   Maximum value of sin function $= 1$ *(A1)*

   (ii) $\dfrac{dy}{dx} = e^x \cos(e^x)$ *(A1)(A1)*

Note: Award *(A1)* for $\cos(e^x)$ and *(A1)* for e^x.

   (iii) $\dfrac{dy}{dx} = 0$ at a maximum   *(R1)*

   $e^x \cos(e^x) = 0$

   $\Rightarrow\; e^x = 0$ (impossible) or $\cos(e^x) = 0$ *(M1)*

   $\Rightarrow\; e^x = \dfrac{\pi}{2} \;\Rightarrow\; x = \ln\dfrac{\pi}{2}$ *(A1)(AG)*

                                                                              [6 marks]

   (d)   (i)   Area $= \displaystyle\int_0^{\ln \pi} \sin(e^x)\,dx$ *(A1)(A1)(A1)*

Note: Award *(A1)* for 0, *(A1)* for $\ln \pi$, *(A1)* for $\sin(e^x)$.

   (ii)   Integral $= 0.90585 = 0.906$ (3 s.f.)   *(G2)*

                                                                              [5 marks]

   (e)
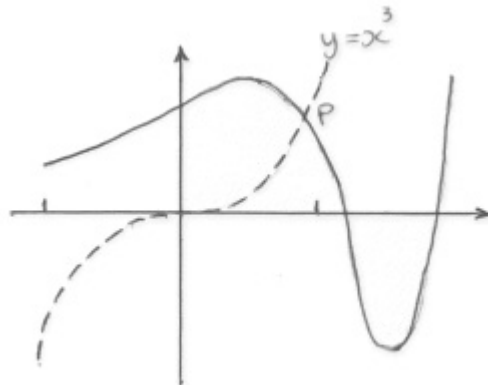
                                                                                        (M1)

   At P, $x = 0.87656 = 0.877$ (3 s.f.)   *(G2)*

                                                                              [3 marks]

                                                                    Total [18 marks]

4.   (a)   (i) $|\boldsymbol{a}| = \sqrt{12^2 + 5^2} = 13$ *(A1)*

(ii) $|\boldsymbol{b}| = \sqrt{6^2 + 8^2} = 10$ *(A1)*

$\Rightarrow$ unit vector in direction of $\boldsymbol{b} = \dfrac{1}{10}(6\boldsymbol{i} + 8\boldsymbol{j})$ *(A1)*

$= 0.6\boldsymbol{i} + 0.8\boldsymbol{j}$

(iii) $\boldsymbol{a} \cdot \boldsymbol{b} = |\boldsymbol{a}||\boldsymbol{b}|\cos\theta$ *(M1)*

$\Rightarrow \cos\theta = \dfrac{12(6) + 5(8)}{13(10)}$ *(A1)*

$= \dfrac{112}{130} = \dfrac{56}{65}$ *(A1)*

[6 marks]

(b)   (i)   Projection of $\boldsymbol{a}$ in direction of $\boldsymbol{b} = \dfrac{\boldsymbol{a} \cdot \boldsymbol{b}}{|\boldsymbol{b}|} = |\boldsymbol{a}|\cos\theta$ *(M1)*

$= \dfrac{112}{10} = 13\left(\dfrac{56}{65}\right) = 11.2$ *(A1)*

(ii) $\boldsymbol{c} = |\boldsymbol{c}| \times$ unit vector in direction of $\boldsymbol{b}$

$= 11.2(0.6\boldsymbol{i} + 0.8\boldsymbol{j})$

$= 6.72\boldsymbol{i} + 8.96\boldsymbol{j}$ *(A1)(A1)*

(iii) $AC^2 = OA^2 - OC^2$ *(M1)*

$AC = \sqrt{13^2 - 11.2^2} = 6.6$ *(A1)*

[6 marks]

Total [12 marks]

5. (a) $\dfrac{\mathrm{d}s}{\mathrm{d}t} = 30 - at \Rightarrow s = 30t - a\dfrac{t^2}{2} + C$ *(A1)(A1)(A1)*

> **Note:** Award *(A1)* for $30t$, *(A1)* for $a\dfrac{t^2}{2}$, *(A1)* for C.

$t = 0 \Rightarrow s = 30(0) - a\dfrac{(0^2)}{2} + C = 0 + C \Rightarrow C = 0$ *(M1)*

$\Rightarrow\ \ s = 30t - \dfrac{1}{2}at^2$ *(A1)*

[5 marks]

(b) (i) $\mathrm{vel} = 30 - 5(0) = 30\ \mathrm{ms}^{-1}$ *(A1)*

(ii) Train will stop when $0 = 30 - 5t \Rightarrow t = 6$ *(M1)*

Distance travelled $= 30t - \dfrac{1}{2}at^2$

(M1)

$= 30(6) - \dfrac{1}{2}(5)(6^2)$

$= 90\,\mathrm{m}$ *(A1)*

$90 < 200 \Rightarrow$ train stops before station.   *(R1)(AG)*

[5 marks]

(c) (i) $0 = 30 - at\ \Rightarrow\ t = \dfrac{30}{a}$ *(A1)*

(ii) $30\left(\dfrac{30}{a}\right) - \dfrac{1}{2}(a)\left(\dfrac{30}{a}\right)^2 = 200$ *(M1)(M1)*

> **Note:** Award *(M1)* for substituting $\dfrac{30}{a}$, *(M1)* for setting equal to 200.

$\Rightarrow \dfrac{900}{a} - \dfrac{450}{a} = \dfrac{450}{a} = 200$ *(A1)*

$\Rightarrow a = \dfrac{450}{200} = \dfrac{9}{4} = 2.25\ \mathrm{ms}^{-2}$ *(A1)*

> **Note:** Do not penalize lack of units in answers.

[5 marks]

Total [15 marks]

6.

> **Note:** Where accuracy is not specified, accept answers with greater than 3 s.f. accuracy, provided they are correct as far as 3 s.f.

(i) (a) $z = \dfrac{197 - 187.5}{9.5} = 1.00$ **(M1)**

$P(Z > 1) = 1 - \Phi(1) = 1 - 0.8413 = 0.1587$

$= 0.159 \,(3 \text{ s.f.})$ **(A1)**

$= 15.9\,\%$ **(A1)**

OR

$P(H > 197) = 0.159$ **(G2)**

$= 15.9\,\%$ **(A1)**

[3 marks]

(b) Finding the 99th percentile

$\Phi(a) = 0.99 \Rightarrow a = 2.327 \,(\text{accept } 2.33)$ **(A1)**

$\Rightarrow 99\,\%$ of heights under $187.5 + 2.327(9.5) = 209.6065$ **(M1)**

$= 210 \,(3 \text{ s.f.})$ **(A1)**

OR

$99\,\%$ of heights under $209.6 = 210 \text{ cm} \,(3 \text{ s.f.})$ **(G3)**

Height of standard doorway $= 210 + 17 = 227 \text{ cm}$ **(A1)**

[4 marks]

(c) (i) Standard error of mean $= \dfrac{4.5}{\sqrt{20}} = 1.006$ **(A1)**

$95\,\%$ confidence interval $\Rightarrow z = 1.960$ **(A1)**

$\left(\dfrac{2412}{20} - 1.96(1.006), \dfrac{2412}{20} + 1.96(1.006) \right)$ **(M1)**

$= (118.6, 122.6)$ **(A1)**

OR

For $m = \dfrac{2412}{20} = 120.6, \sigma = 4.5, n = 20$ **(M1)**

$95\,\%$ confidence interval for sample mean $= (118.6, 122.6)$ **(G3)**

[4 marks]

(ii) Probability that interval in part (i) does not contain the mean

$= 0.05 \,(\text{or } 5\,\%)$ **(A1)**

[1 mark]

Question 6 continued

(ii) (a)   The value of *y* is expected to increase   **(A1)**
            (as s_{xy} (or *r*) is positive).

                                                                                        [1 mark]

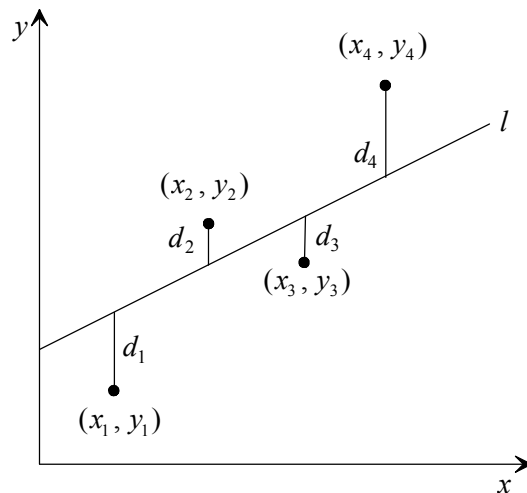   (b) $(y - \bar{y}) = \dfrac{s_{xy}}{s_x^2}(x - \bar{x})$

            $(y - 63.12) = \dfrac{74.66}{10.25^2}(x - 56.45)$ **(M1)(A1)**

            $\Rightarrow y = 0.7106x + 23.01 = 0.711x + 23.0$ (3 s.f.)   **(A1)**

                                                                                        [3 marks]

      (c) $y = 0.7106(76) + 23.01 = 77.02 = 77.0$ (accept 77)   **(M1)(A1)**

                                                                                        [2 marks]

      (d)

Note: Award **(A1)** for a scatter diagram with at least 3 points.
           Award **(A1)** for line *l* drawn with vertical distances from points to *l* marked.

            Calculate the sum of the squares of the vertical distances, *i.e.* $\sum d_i^2$ **(R1)**

            The least squares regression line is the line that makes the sum of squares a
            minimum.   **(R1)**

                                                                                        [4 marks]

                                                                                        continued…

Question 6 continued

(iii) (a) $400.7 + a = 510 \quad \Rightarrow \quad a = 109.3$ **(A1)**
$400.7 + b = 550 \quad \Rightarrow \quad b = 149.3$ **(A1)**
$109.3 + c = 150 \text{ or } 149.3 + c = 190 \Rightarrow c = 40.7$ **(A1)**

[3 marks]

(b) $\chi^2 = \dfrac{(400.7 - 390)^2}{400.7} + \dfrac{(109.3 - 120)^2}{109.3} + \dfrac{(149.3 - 160)^2}{149.3} + \dfrac{(40.7 - 30)^2}{40.7}$ **(M1)**

$= 4.913 = 4.91$ **(A1)**

> **Notes:** If integer values only used for expected frequencies, accept $\chi^2 = 5.18$ for full credit.
> If 3 s.f. values used for a, b and c, accept $\chi^2 = 5.00$ for full credit.

OR

$\chi^2 = 4.925 = 4.93$ **(G2)**

> **Note:** Calculators with built-in χ^2 test do not round off expected values and therefore give
> a slightly different answer.

[2 marks]

(c) (i) The attitude does depend on where the person lives (urban or rural).   **(A1)**

(ii) For 1 degree of freedom, 95% of χ^2 values are less than 3.841. As   **(A1)**
$4.913 > 3.841$, the probability of obtaining this value is less than 5% so
the hypothesis of independence is rejected.   **(R1)**

OR

The probability of obtaining a value of χ^2 or greater is 0.0265 or 2.65%.   **(G1)**
As this value is less than 5%, the hypothesis of independence is rejected.   **(R1)**

[3 marks]

Total [30 marks]

7. **(i)** **(a)** $x_1 = -0.790$ and $x_2 = 1.79$ *(A1)(A1)*

[2 marks]

(b) **(i)** $a = -0.790$ *(A1)*

(ii) $b = 1.79$ *(A1)*

[2 marks]

(c) When x is large, the value of $g(x)$ becomes much larger than the value of $2x^3$. *(R1)*

As a consequence, the value of $\dfrac{2x^3}{g(x)}$ approaches 0. Thus $f(x)$ approaches 1. *(R1)(AG)*

[2 marks]

(d) **(i)** At A, $x = -1$ *(A1)*

(ii) At B, $x = 1$ *(A1)*

[2 marks]

(e) Horizontal point of inflexion *(A2)*

OR

Gradient of tangent $= 0 \Rightarrow f'(x) = 0$ *(A1)*

Point of inflexion $\Rightarrow f''(x) = 0$ *(A1)*

[2 marks]

(ii) **(a)** $\dfrac{dy}{dx} = (2x)\left[\dfrac{1}{2}(1+x^2)^{-\frac{1}{2}}(2x)\right] + (2)(1+x^2)^{\frac{1}{2}}$ *(M1)(M1)*

Note: Award *(M1)* for correct use of product rule, *(M1)* for correct use of chain rule.

$\dfrac{dy}{dx} = \dfrac{2x^2}{\sqrt{1+x^2}} + 2\sqrt{1+x^2}$ *(A1)*

[3 marks]

(b) $u = 1 + x^2 \Rightarrow \dfrac{du}{dx} = 2x$ (or $du = 2x\,dx$) *(M1)*

$\Rightarrow \int 2x\sqrt{1+x^2}\,dx = \int u^{\frac{1}{2}}\left(\dfrac{du}{dx}\right)dx = \int u^{\frac{1}{2}}\,du$ *(M1)*

$= \dfrac{2}{3}u^{3/2} + C = \dfrac{2}{3}(1+x^2)^{\frac{3}{2}} + C$ *(A1)(AG)*

Note: Accept proof by differentiation.

[3 marks]

(c) $R = \int_0^k 2x\sqrt{1+x^2}\,dx = \left[\dfrac{2}{3}(1+x^2)^{3/2}\right]_0^k = 1$ *(M1)*

$\Rightarrow \dfrac{2}{3}(1+k^2)^{\frac{3}{2}} - \dfrac{2}{3}(1) = 1 \Rightarrow (1+k^2)^{\frac{3}{2}} = \dfrac{5}{2}$ *(M1)*

$\Rightarrow k = 0.9176 = 0.918$ *(A1)*

OR

$k = 0.918$ *(G3)*

[3 marks]

Question 7 continued

(iii)　(a)　(i)　At $x = a$, $h(x) = a^{\frac{1}{5}}$

$$h'(x) = \frac{1}{5}x^{-\frac{4}{5}} \Rightarrow h'(a) = \frac{1}{5a^{\frac{4}{5}}} = \text{ gradient of tangent} \qquad \textbf{\textit{(A1)}}$$

$$\Rightarrow \quad y - a^{\frac{1}{5}} = \frac{1}{5a^{\frac{4}{5}}}(x-a) = \frac{1}{5a^{\frac{4}{5}}}x - \frac{1}{5}a^{\frac{1}{5}} \qquad \textbf{\textit{(M1)}}$$

$$\Rightarrow \quad y = \frac{1}{5a^{\frac{4}{5}}}x + \frac{4}{5}a^{\frac{1}{5}} \qquad \textbf{\textit{(A1)}}$$

(ii)　tangent intersects x-axis $\Rightarrow y = 0$

$$\Rightarrow \quad \frac{1}{5a^{\frac{4}{5}}}x = -\frac{4}{5}a^{\frac{1}{5}} \qquad \textbf{\textit{(M1)}}$$

$$\Rightarrow \quad x = 5a^{\frac{4}{5}}\left(-\frac{4}{5}a^{\frac{1}{5}}\right) = -4a \qquad \textbf{\textit{(M1)(AG)}}$$
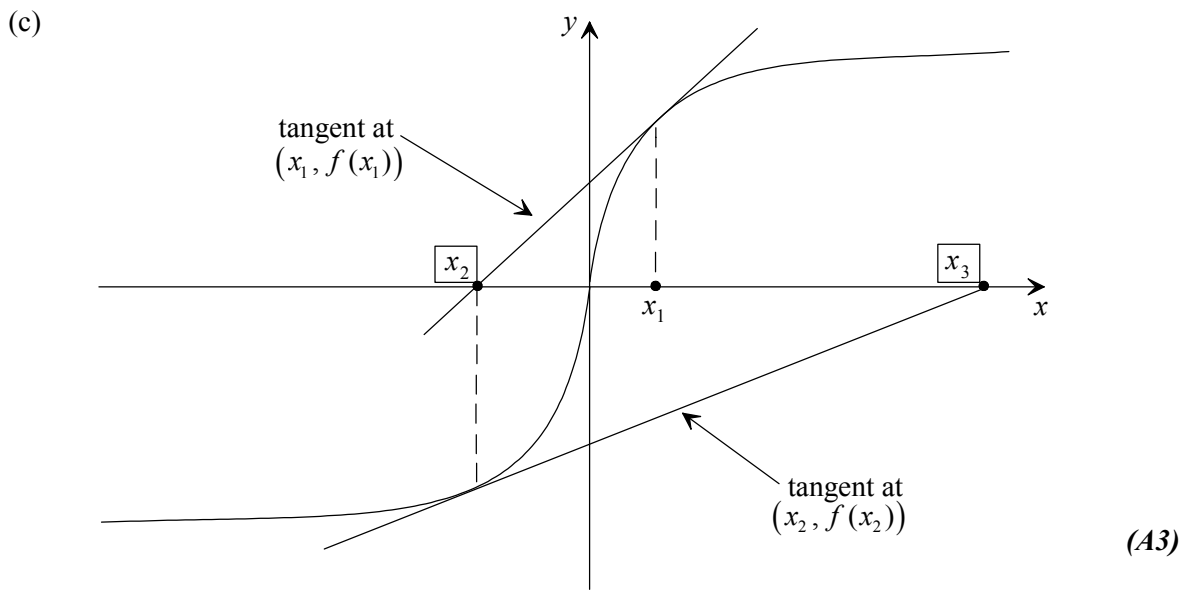
[5 marks]

(b)　From above result, it may be deduced $x_{n+1} = -4x_n$ 　　　　*(M1)*

(i)　$\Rightarrow \quad x_2 = -4(0.5) = -2$ 　　　　*(A1)*

(ii)　$\Rightarrow \quad x_5 = -4x_4 = -4(-4x_3) = 16(-4x_2) = 128$ 　　　　*(A1)*

[3 marks]

(c)

tangent at $(x_1, f(x_1))$

tangent at $(x_2, f(x_2))$

x_2　x_1　x_3

(A3)

Note: Award *(A1)* for the tangents, and *(A1)* for each point x_2, x_3.

[3 marks]

Total [30 marks]

8.   (i)   (a)   (i) $P = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$ *(A1)*

(ii) $Q = \begin{pmatrix} 1 & 0 \\ 0 & 5 \end{pmatrix}$ *(A1)*

[2 marks]

(b)   (i) $PQ = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ 0 & 5 \end{pmatrix}$ *(M1)*

$= \begin{pmatrix} 1(1)+0(0) & 1(0)+0(5) \\ 0(1)+(-1)0 & 0(0)+(-1)5 \end{pmatrix}$ *(A1)*

$E_1 = \begin{pmatrix} 1 & 0 \\ 0 & -5 \end{pmatrix}$ *(AG)*

Note: Award *(M0)(A1)* if order of matrices reversed.

[2 marks]

(ii) $M = E_3 E_2 E_1 \;\Rightarrow\; E_2 = E_3^{-1} M E_1^{-1}$ *(M1)*

$E_3^{-1} = \begin{pmatrix} 1 & 0 \\ -3 & 1 \end{pmatrix} \quad E_1^{-1} = \begin{pmatrix} 1 & 0 \\ 0 & -\dfrac{1}{5} \end{pmatrix}$ *(A1)(A1)*

$E_2 = \begin{pmatrix} 1 & 0 \\ -3 & 1 \end{pmatrix}\begin{pmatrix} 1 & 3 \\ 3 & 4 \end{pmatrix}\begin{pmatrix} 1 & 0 \\ 0 & -\dfrac{1}{5} \end{pmatrix}$

$= \begin{pmatrix} 1 & -\dfrac{3}{5} \\ 0 & 1 \end{pmatrix}$ *(A1)*

[4 marks]

(c)   (i) $\Delta' = \begin{pmatrix} 1 & 3 \\ 3 & 4 \end{pmatrix}\begin{pmatrix} 1 & 1 & 3 \\ 0 & 2 & 0 \end{pmatrix}$ *(M1)*

$= \begin{pmatrix} 1 & 7 & 3 \\ 3 & 11 & 9 \end{pmatrix}$ *(A1)*

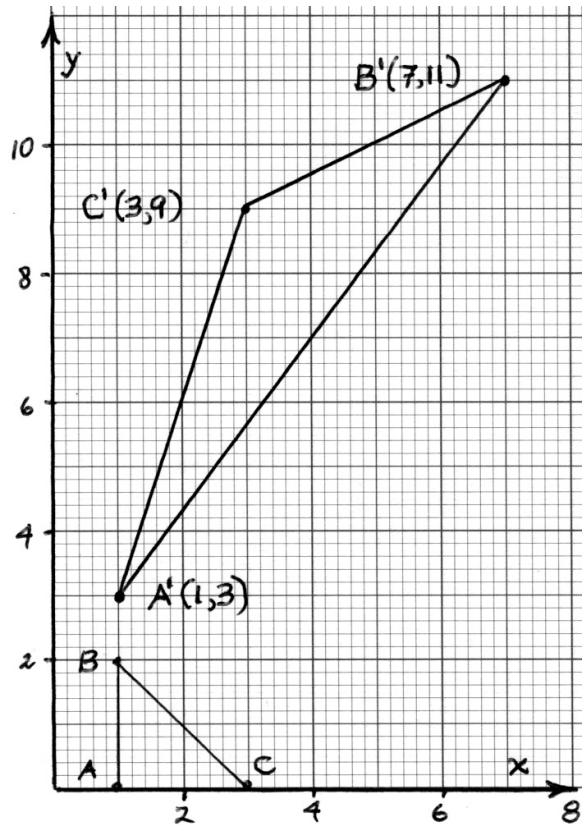$\Rightarrow A'(1, 3), B'(7, 11), C'(3, 9)$ *(A1)*

OR

$A'(1, 3), B'(7, 11), C'(3, 9)$ *(A1)(A1)(A1)*

continued…

Question 8 (i)(c) continued

(ii)

(A1)

| **Note:** | Do not penalize a correctly drawn graph using the wrong scale. |

(iii)   Area $\Delta A'B'C' = |\det M| \times$ Area ΔABC **(M1)**

$$= |-5| \times \left(\frac{1}{2}\right) 2(2) = 10$$ **(A1)**

OR

Area $\Delta A'B'C' = 10$ **(A2)**

[6 marks]

(d)   Transformations represented by 2×2 matrices map straight line into straight lines.   **(M1)**
Two points on original line are: $(0,3)$ and $(3,0)$. Images are $(9,12)$ and $(3,9)$.   **(A1)**

Equation of transformed line: $(y-12) = \dfrac{12-9}{9-3}(x-9)$ **(M1)**

$\Rightarrow \quad y = 0.5x + 7.5$ **(A1)**

OR

Position vector of point on line $= \begin{pmatrix} x \\ -x+3 \end{pmatrix}$ **(M1)**

$$\begin{pmatrix} 1 & 3 \\ 3 & 4 \end{pmatrix}\begin{pmatrix} x \\ -x+3 \end{pmatrix} = \begin{pmatrix} x-3x+9 \\ 3x-4x+12 \end{pmatrix} = \begin{pmatrix} -2x+9 \\ -x+12 \end{pmatrix} = \begin{pmatrix} x' \\ y' \end{pmatrix}$$ **(M1)**

$x' = -2x+9 \Rightarrow x = -\dfrac{1}{2}x' + 4.5 \Rightarrow y' = -\left(-\dfrac{1}{2}x' + 4.5\right) + 12$ **(A1)**

Equation of transformed line: $y = 0.5x + 7.5$ **(A1)**

[4 marks]

continued…

Question 8 continued

(ii)   (a)   (i) $\begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} 7 \\ 1 \end{pmatrix} = \begin{pmatrix} -5 \\ 5 \end{pmatrix}$ *(M1)(A1)*

(ii) $\Rightarrow 7\cos\theta - \sin\theta = -5 \Rightarrow 49\cos\theta - 7\sin\theta = -35$

$7\sin\theta + \cos\theta = 5 \Rightarrow \cos\theta + 7\sin\theta = 5$ *(M1)*

$\Rightarrow 50\cos\theta = -30 \Rightarrow \cos\theta = -0.6$ *(A1)*

$\Rightarrow \sin\theta = 7(-0.6) + 5 = 0.8$ *(A1)*

$\Rightarrow \boldsymbol{R} = \begin{pmatrix} -0.6 & -0.8 \\ 0.8 & -0.6 \end{pmatrix}$ *(A1)*

[6 marks]

(b)   (i) $\begin{pmatrix} -5 \\ 5 \end{pmatrix} = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} 7 \\ 1 \end{pmatrix} + \begin{pmatrix} a \\ b \end{pmatrix}$ *(M1)*

$= \begin{pmatrix} -1 + a \\ 7 + b \end{pmatrix}$

$\Rightarrow a = -4, b = -2$ *(A1)(A1)*

(ii)   If *(h, k)* is centre of rotation, then $\begin{pmatrix} h \\ k \end{pmatrix}$ is invariant.

$\Rightarrow \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} h \\ k \end{pmatrix} + \begin{pmatrix} -4 \\ -2 \end{pmatrix} = \begin{pmatrix} -k-4 \\ h-2 \end{pmatrix} = \begin{pmatrix} h \\ k \end{pmatrix}$ *(M1)*

$\Rightarrow h + k = -4$ and $h - k = 2$

$\Rightarrow h = -1$ and $k = -3$ *(A1)(A1)*

[6 marks]

Total [30 marks]