International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2013

MATHEMATICS

Higher Level

Paper 1

Instructions to Examiners

Abbreviations

M Marks awarded for attempting to use a correct **Method**; working must be seen.

(M) Marks awarded for **Method**; may be implied by **correct** subsequent working.

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

(A) Marks awarded for an **Answer** or for **Accuracy**; may be implied by **correct** subsequent working.

R Marks awarded for clear **Reasoning**.

N Marks awarded for **correct** answers if **no** working shown.

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

Using the markscheme

1 General

Mark according to Scoris instructions and the document "**Mathematics HL: Guidance for e-marking May 2013**". It is essential that you read this document before you start marking. In particular, please note the following:

- Marks must be recorded using the annotation stamps. Please check that you are entering marks for the right question.
- If a part is **completely correct**, (and gains all the "must be seen" marks), use the ticks with numbers to stamp full marks.
- If a part is completely wrong, stamp ***A0*** by the final answer.
- If a part gains anything else, it **must** be recorded using **all** the annotations.
- All the marks will be added and recorded by Scoris.

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 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, *eg* ***M1A1***, this usually means ***M1*** for an **attempt** to use an appropriate method (*eg* substitution into a formula) and ***A1*** for using the **correct** values.
- Where the markscheme specifies ***(M2)***, ***N3***, *etc.*, do **not** split the marks.
- Once a correct answer to a question or part-question is seen, ignore further working.

3 *N* marks

*Award **N** marks for **correct** answers where there is **no** working.*

- Do **not** award a mixture of ***N*** and other marks.
- There may be fewer ***N*** marks available than the total of ***M***, ***A*** and ***R*** marks; this is deliberate as it penalizes candidates for not following the instruction to show their working.

4 Implied marks

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

- Normally the correct work is seen or implied in the next line.
- Marks **without** brackets can only be awarded for work that is **seen**.

5 Follow through marks

*Follow through (****FT****) marks are awarded where an incorrect answer from one* ***part*** *of a question is used correctly in* ***subsequent*** *part(s). To award* ***FT*** *marks,* ***there must be working present*** *and not just a final answer based on an incorrect answer to a previous part.*

- If the question becomes much simpler because of an error then use discretion to award fewer ***FT*** marks.
- If the error leads to an inappropriate value (*eg* $\sin\theta = 1.5$), do not award the mark(s) for the final answer(s).
- Within a question part, once an error is made, no further **dependent *A*** marks can be awarded, but ***M*** marks may be awarded if appropriate.
- Exceptions to this rule will be explicitly noted on the markscheme.

6 Mis-read

*If a candidate incorrectly copies information from the question, this is a mis-read (****MR****). A candidate should be penalized only once for a particular mis-read. Use the* ***MR*** *stamp to indicate that this has been a misread. Then deduct the first of the marks to be awarded, even if this is an* ***M*** *mark, but award all others so that the candidate only loses one mark.*

- 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 (*eg* $\sin\theta = 1.5$), do not award the mark(s) for the final answer(s).

7 Discretionary marks *(d)*

An examiner uses discretion to award a mark on the rare occasions when the markscheme does not cover the work seen. In such cases the annotation DM should be used and a brief ***note*** *written next to the mark explaining this decision.*

8 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 in doubt, contact your team leader for advice.

- Alternative methods for complete questions are indicated by **METHOD 1**, **METHOD 2**, *etc*.
- Alternative solutions for part-questions are indicated by **EITHER** . . . **OR**.
- Where possible, alignment will also be used to assist examiners in identifying where these alternatives start and finish.

9 Alternative forms

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

- As this is an international examination, accept all alternative forms of **notation**.
- In the markscheme, equivalent **numerical** and **algebraic** forms will generally be written in brackets immediately following the answer.
- In the markscheme, **simplified** answers, (which candidates often do not write in examinations), will generally appear in brackets. Marks should be awarded for either the form preceding the bracket or the form in brackets (if it is seen).

Example: for differentiating $f(x) = 2\sin(5x-3)$, the markscheme gives:

$$f'(x) = \left(2\cos(5x-3)\right)5 \quad \left(=10\cos(5x-3)\right)$$ ***A1***

Award ***A1*** for $\left(2\cos(5x-3)\right)5$, even if $10\cos(5x-3)$ is not seen.

10 Accuracy of Answers

Candidates should ***NO LONGER*** *be penalized for an accuracy error* ***(AP)****.*

If the level of accuracy is specified in the question, a mark will be allocated for giving the answer to the required accuracy. When this is not specified in the question, all numerical answers should be given exactly or correct to three significant figures. Please check work carefully for ***FT****.*

11 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.

12 Calculators

No calculator is allowed. The use of any calculator on paper 1 is malpractice, and will result in no grade awarded. If you see work that suggests a candidate has used any calculator, please follow the procedures for malpractice. Examples: finding an angle, given a trig ratio of 0.4235.

13 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.

SECTION A

1. (a) modulus $=\sqrt{8}$ *A1*

argument $=\dfrac{\pi}{4}$ (accept 45°) *A1*

Note: *A0* if extra values given.

[2 marks]

(b) **METHOD 1**

$w^4 z^6 = 64e^{\pi i} \times e^{5\pi i}$ *(A1)(A1)*

Note: Allow alternative notation.

$= 64e^{6\pi i}$ *(M1)*

$= 64$ *A1*

METHOD 2

$w^4 = -64$ *(M1)(A1)*

$z^6 = -1$ *(A1)*

$w^4 z^6 = 64$ *A1*

[4 marks]

Total [6 marks]

2. (a) $\overrightarrow{AB} = \begin{pmatrix} 1 \\ 0 \\ 5 \end{pmatrix} - \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 0 \\ -2 \\ 2 \end{pmatrix}, \ \overrightarrow{AC} = \begin{pmatrix} 2 \\ -1 \\ 4 \end{pmatrix} - \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 1 \\ -3 \\ 1 \end{pmatrix}$ *A1A1*

Note: Award the above marks if the components are seen in the line below.

$\overrightarrow{AB} \times \overrightarrow{AC} = \begin{vmatrix} i & j & k \\ 0 & -2 & 2 \\ 1 & -3 & 1 \end{vmatrix} = \begin{pmatrix} 4 \\ 2 \\ 2 \end{pmatrix}$ *(M1)A1*

[4 marks]

(b) area $=\dfrac{1}{2}\left|\left(\overrightarrow{AB} \times \overrightarrow{AC}\right)\right|$ *(M1)*

$=\dfrac{1}{2}\sqrt{4^2+2^2+2^2} = \dfrac{1}{2}\sqrt{24}\left(=\sqrt{6}\right)$ *A1*

Note: Award ***M0A0*** for attempts that do not involve the answer to (a).

[2 marks]

Total [6 marks]

3. **METHOD 1**

$A^{-1} = \frac{1}{-1}\begin{pmatrix} 1 & -2 \\ -1 & 1 \end{pmatrix}\left(= \begin{pmatrix} -1 & 2 \\ 1 & -1 \end{pmatrix}\right)$ ***(M1)A1***

$X = A^{-1}BA = \begin{pmatrix} -1 & 2 \\ 1 & -1 \end{pmatrix}\begin{pmatrix} 4 & -3 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} 1 & 2 \\ 1 & 1 \end{pmatrix}$ ***M1***

$\begin{pmatrix} -2 & 5 \\ 3 & -4 \end{pmatrix}\begin{pmatrix} 1 & 2 \\ 1 & 1 \end{pmatrix} \text{or} \begin{pmatrix} -1 & 2 \\ 1 & -1 \end{pmatrix}\begin{pmatrix} 1 & 5 \\ 2 & 3 \end{pmatrix} = \begin{pmatrix} 3 & 1 \\ -1 & 2 \end{pmatrix}$ ***(M1)A1***

Note: Accept the answer $\frac{1}{-1}\begin{pmatrix} -3 & -1 \\ 1 & -2 \end{pmatrix}$.

METHOD 2

$X = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$

$AX = BA$ ***M1***

$\begin{pmatrix} 1 & 2 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} 4 & -3 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} 1 & 2 \\ 1 & 1 \end{pmatrix}$

$\begin{pmatrix} a+2c & b+2d \\ a+c & b+d \end{pmatrix} = \begin{pmatrix} 1 & 5 \\ 2 & 3 \end{pmatrix}$ ***(M1)(A1)***

$a+2c=1$
$b+2d=5$
$a+c=2$
$b+d=3$
$a=3, b=1, c=-1, d=2$ ***(M1)A1***

[5 marks]

METHOD 3

$A^{-1} = \frac{1}{-1}\begin{pmatrix} 1 & -2 \\ -1 & 1 \end{pmatrix}\left(= \begin{pmatrix} -1 & 2 \\ 1 & -1 \end{pmatrix}\right)$ ***(M1)A1***

$X = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$

$\begin{pmatrix} 1 & 2 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} a & b \\ c & d \end{pmatrix}\begin{pmatrix} -1 & 2 \\ 1 & -1 \end{pmatrix} = \begin{pmatrix} 4 & -3 \\ 1 & 1 \end{pmatrix}$

$a=3, b=1, c=-1, d=2$ ***(M1)(M1)A1***

[5 marks]

4. $\int_0^{\frac{\pi}{2}} x\sin x\mathrm{d}x$ ***M1***

$= \left[-x\cos x\right]_0^{\frac{\pi}{2}} + \int_0^{\frac{\pi}{2}} \cos x\mathrm{d}x$ ***M1(A1)***

Note: Condone the absence of limits or wrong limits to this point.

$= \left[-x\cos x + \sin x\right]_0^{\frac{\pi}{2}}$ ***A1***

$= 1$ ***A1***

[5 marks]

5. $V = 0.5\pi r^2$ ***(A1)***

EITHER

$\frac{dV}{dr} = \pi r$ ***A1***

$\frac{dV}{dt} = 4$ ***(A1)***

applying chain rule ***M1***

for example $\frac{dr}{dt} = \frac{dV}{dt} \times \frac{dr}{dV}$

OR

$\frac{dV}{dt} = \pi r \frac{dr}{dt}$ ***M1A1***

$\frac{dV}{dt} = 4$ ***(A1)***

THEN

$\frac{dr}{dt} = 4 \times \frac{1}{\pi r}$ ***A1***

when $r = 20$, $\frac{dr}{dt} = \frac{4}{20\pi}$ or $\frac{1}{5\pi}$ (cm s^{-1}) ***A1***

Note: Allow h instead of 0.5 up until the final ***A1***.

[6 marks]

6. when $n=1$, $(\boldsymbol{A}+\boldsymbol{I})^1 = 2^0(\boldsymbol{A}+\boldsymbol{I})$ (or $1\times(\boldsymbol{A}+\boldsymbol{I})$) ***A1***

so true for $n=1$

assume the statement is true for $n=k$ ***M1***

$(\boldsymbol{A}+\boldsymbol{I})^k = 2^{k-1}(\boldsymbol{A}+\boldsymbol{I})$

Note: Award ***M1*** only if assumption of truth is clear.

$(\boldsymbol{A}+\boldsymbol{I})^{k+1} = (\boldsymbol{A}+\boldsymbol{I})^k(\boldsymbol{A}+\boldsymbol{I})$

$= 2^{k-1}(\boldsymbol{A}+\boldsymbol{I})(\boldsymbol{A}+\boldsymbol{I})$ ***M1***

$= 2^{k-1}(\boldsymbol{A}^2+\boldsymbol{IA}+\boldsymbol{AI}+\boldsymbol{I}^2)$ ***M1***

$= 2^{k-1}(2\boldsymbol{A}+2\boldsymbol{I})$ ***A1***

$= 2^k(\boldsymbol{A}+\boldsymbol{I})$

therefore if true for $n=k$ then true for $n=k+1$; as true for $n=1$ so true for all $n(\in\mathbb{Z}^+)$ ***R1***

Note: Only award ***R1*** if all three ***M*** marks have been awarded.

[6 marks]

7. $8y\times\frac{1}{x}+8\frac{\mathrm{d}y}{\mathrm{d}x}\ln x-4x+8y\frac{\mathrm{d}y}{\mathrm{d}x}=0$ ***M1A1A1***

Note: ***M1*** for attempt at implicit differentiation. ***A1*** for differentiating $8y\ln x$, ***A1*** for differentiating the rest.

when $x=1$, $8y\times0-2\times1+4y^2=7$ ***(M1)***

$y^2=\frac{9}{4}\Rightarrow y=\frac{3}{2}$ (as $y>0$) ***A1***

at $\left(1,\frac{3}{2}\right)$ $\frac{\mathrm{d}y}{\mathrm{d}x}=-\frac{2}{3}$ ***A1***

$y-\frac{3}{2}=-\frac{2}{3}(x-1)$ or $y=-\frac{2}{3}x+\frac{13}{6}$ ***A1***

[7 marks]

8. **METHOD 1**

$$d = \frac{1}{\log_8 x} - \frac{1}{\log_2 x}$$ ***(M1)***

$$= \frac{\log_2 8}{\log_2 x} - \frac{1}{\log_2 x}$$ ***(M1)***

Note: Award this ***M1*** for a correct change of base anywhere in the question.

$$= \frac{2}{\log_2 x}$$ ***(A1)***

$$\frac{20}{2}\left(2 \times \frac{1}{\log_2 x} + 19 \times \frac{2}{\log_2 x}\right)$$ ***M1***

$$= \frac{400}{\log_2 x}$$ ***(A1)***

$$100 = \frac{400}{\log_2 x}$$

$$\log_2 x = 4 \Rightarrow x = 2^4 = 16$$ ***A1***

METHOD 2

$$20^{\text{th}} \text{ term } = \frac{1}{\log_{2^{39}} x}$$ ***A1***

$$100 = \frac{20}{2}\left(\frac{1}{\log_2 x} + \frac{1}{\log_{2^{39}} x}\right)$$ ***M1***

$$100 = \frac{20}{2}\left(\frac{1}{\log_2 x} + \frac{\log_2 2^{39}}{\log_2 x}\right)$$ ***M1(A1)***

Note: Award this ***M1*** for a correct change of base anywhere in the question.

$$100 = \frac{400}{\log_2 x}$$ ***(A1)***

$$\log_2 x = 4 \Rightarrow x = 2^4 = 16$$ ***A1***

continued …

Question 8 continued

METHOD 3

$$\frac{1}{\log_2 x}+\frac{1}{\log_8 x}+\frac{1}{\log_{32} x}+\frac{1}{\log_{128} x}+\dots$$

$$\frac{1}{\log_2 x}+\frac{\log_2 8}{\log_2 x}+\frac{\log_2 32}{\log_2 x}+\frac{\log_2 128}{\log_2 x}+\dots$$ ***(M1)(A1)***

Note: Award this ***M1*** for a correct change of base anywhere in the question.

$$=\frac{1}{\log_2 x}(1+3+5+\dots)$$ ***A1***

$$=\frac{1}{\log_2 x}\left(\frac{20}{2}(2+38)\right)$$ ***(M1)(A1)***

$$100=\frac{400}{\log_2 x}$$

$$\log_2 x=4 \Rightarrow x=2^4=16$$ ***A1***

[6 marks]

9. **Note: Be aware that an unjustified assumption of independence will also lead to $\mathrm{P}(\mathrm{B}) = 0.25$, but is an invalid method.**

METHOD 1

$\mathrm{P}(A' | B') = 1 - \mathrm{P}(A | B') = 1 - 0.6 = 0.4$ ***M1A1***

$\mathrm{P}(A' | B') = \dfrac{\mathrm{P}(A' \cap B')}{\mathrm{P}(B')}$

$\mathrm{P}(A' \cap B') = \mathrm{P}\big((A \cup B)'\big) = 1 - 0.7 = 0.3$ ***A1***

$0.4 = \dfrac{0.3}{\mathrm{P}(B')} \Rightarrow \mathrm{P}(B') = 0.75$ ***(M1)A1***

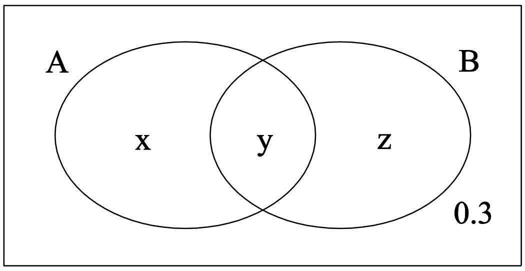
$\mathrm{P}(B) = 0.25$ ***A1***

(this method can be illustrated using a tree diagram)

[6 marks]

METHOD 2

$\mathrm{P}\big((A \cup B)'\big) = 1 - 0.7 = 0.3$ ***A1***



$\mathrm{P}(A | B') = \dfrac{x}{x + 0.3} = 0.6$ ***M1A1***

$x = 0.6x + 0.18$

$0.4x = 0.18$

$x = 0.45$ ***A1***

$\mathrm{P}(A \cup B) = x + y + z$

$\mathrm{P}(B) = y + z = 0.7 - 0.45$ ***(M1)***

$= 0.25$ ***A1***

[6 marks]

METHOD 3

$\dfrac{\mathrm{P}(A \cap B')}{\mathrm{P}(B')} = 0.6$ (or $\mathrm{P}(A \cap B') = 0.6\mathrm{P}(B')$) ***M1***

$\mathrm{P}(A \cap B') = \mathrm{P}(A \cup B) - \mathrm{P}(B)$ ***M1A1***

$\mathrm{P}(B') = 1 - \mathrm{P}(B)$

$0.7 - \mathrm{P}(B) = 0.6 - 0.6\mathrm{P}(B)$ ***M1(A1)***

$0.1 = 0.4\mathrm{P}(B)$

$\mathrm{P}(B) = \dfrac{1}{4}$ ***A1***

[6 marks]

10. (a) $\sin\left(\pi x^{-1}\right)=0 \ \dfrac{\pi}{x}=\pi, 2\pi\ (...)$ *(A1)*

$x=1, \dfrac{1}{2}, \dfrac{1}{3}, \dfrac{1}{4}, \dfrac{1}{5}, \dfrac{1}{6}, \dfrac{1}{7}, \dfrac{1}{8}, \dfrac{1}{9}, \dfrac{1}{10}$ ***A1***

[2 marks]

(b) $\left[\cos(\pi x^{-1})\right]_{\frac{1}{n+1}}^{\frac{1}{n}}$ ***M1***

$=\cos\left(\pi n\right)-\cos\left(\pi(n+1)\right)$ ***A1***

$=2$ when n is even and $=-2$ when n is odd ***A1***

[3 marks]

(c) $\int_{0.1}^{1}\left|\pi x^{-2}\sin(\pi x^{-1})\right|\mathrm{d}x=2+2+...+2=18$ ***(M1)A1***

[2 marks]

Total [7 marks]

SECTION B

11. (a) (i) $\cos\left(\frac{\pi}{6}\right)\cos x - \sin\left(\frac{\pi}{6}\right)\sin x$ ***M1***

$\frac{\sqrt{3}}{2}\cos x - \frac{1}{2}\sin x$ ***A1***

(ii) $\frac{\sqrt{3}}{2}\cos x - \frac{1}{2}\sin x = \frac{1}{2}$ ***(M1)***

$\cos\left(\frac{\pi}{6} + x\right) = \frac{1}{2}$ ***M1***

$\frac{\pi}{6} + x = \frac{\pi}{3}$ or $\frac{5\pi}{3}$ ***(A1)(A1)***

$x = \frac{\pi}{6}$ or $\frac{3\pi}{2}$ ***A1***

[7 marks]

(b) (i) **METHOD 1**

substitute $x = 1$ ***M1***

$p(1) = 0$ ***A1***

hence $x = 1$ is a zero ***AG***

METHOD 2

Correct result when dividing by $x - 1$ ***A1***

Statement that remainder is zero ***R1***

hence $x = 1$ is a zero ***AG***

continued …

Question 11 continued

(ii) $x = 1$ is a root **_A1_**
valid method, for example, dividing or comparing coefficients **_(M1)_**
(may be seen in (b)(i))

other roots are -1 and $\frac{1}{2}$ **_A1A1_**

(iii) $2\sin\theta\cos\theta\cos\theta + \sin^2\theta$ **_M1_**

$2\sin\theta\left(1-\sin^2\theta\right)+\sin^2\theta$ **_(A1)_**

$\left(2\sin\theta - 2\sin^3\theta + \sin^2\theta\right)$

(iv) $2\sin\theta - 2\sin^3\theta + \sin^2\theta = 1$ **_(A1)_**

$\sin\theta = -1, \frac{1}{2}, 1$ **_A1_**

$\theta = \frac{\pi}{6}, \ \frac{5\pi}{6}, \frac{\pi}{2}, \frac{3\pi}{2}$ **_A1A1_**

Note: Award ***A1*** for two correct solutions, ***A2*** for four correct solutions.

[12 marks]

Total [19 marks]

12. (a) $4(x-0.5)^2+4$ *A1A1*

Note: *A1* for two correct parameters, *A2* for all three correct.

[2 marks]

(b) translation $\begin{pmatrix}0.5\\0\end{pmatrix}$ (allow "0.5 to the right") *A1*

stretch parallel to y-axis, scale factor 4 (allow vertical stretch or similar) *A1*

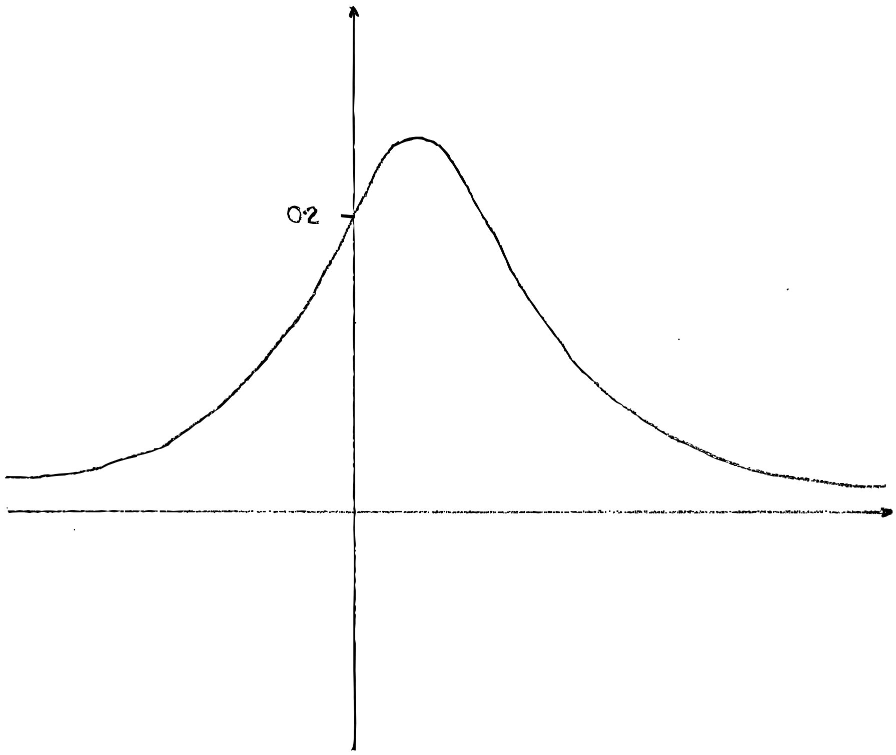
translation $\begin{pmatrix}0\\4\end{pmatrix}$ (allow "4 up") *A1*

Note: All transformations must state magnitude and direction.

Note: First two transformations can be in either order. It could be a stretch followed by a single translation of $\begin{pmatrix}0.5\\4\end{pmatrix}$. If the vertical translation is before the stretch it is $\begin{pmatrix}0\\1\end{pmatrix}$.

[3 marks]

(c)



general shape (including asymptote and single maximum in first quadrant), *A1*

intercept $\left(0, \frac{1}{5}\right)$ **or** maximum $\left(\frac{1}{2}, \frac{1}{4}\right)$ shown *A1*

[2 marks]

continued ...

Question 12 continued

(d) $0 < f(x) \le \frac{1}{4}$ ***A1A1***

> **Note**: ***A1*** for $\le \frac{1}{4}$, ***A1*** for $0 <$.

[2 marks]

(e) let $u = x - \frac{1}{2}$ ***A1***

$\frac{\mathrm{d}u}{\mathrm{d}x} = 1$ (or $\mathrm{d}u = \mathrm{d}x$) ***A1***

$\int \frac{1}{4x^2 - 4x + 5}\mathrm{d}x = \int \frac{1}{4\left(x - \frac{1}{2}\right)^2 + 4}\mathrm{d}x$ ***A1***

$\int \frac{1}{4u^2 + 4}\mathrm{d}u = \frac{1}{4}\int \frac{1}{u^2 + 1}\mathrm{d}u$ ***AG***

> **Note:** If following through an incorrect answer to part (a), do not award final ***A1*** mark.

[3 marks]

(f) $\int_1^{3.5} \frac{1}{4x^2 - 4x + 5}\mathrm{d}x = \frac{1}{4}\int_{0.5}^{3} \frac{1}{u^2 + 1}\mathrm{d}u$ ***A1***

> **Note:** ***A1*** for correct change of limits. Award also if they do not change limits but go back to x values when substituting the limit (even if there is an error in the integral).

$\frac{1}{4}\left[\arctan(u)\right]_{0.5}^{3}$ ***(M1)***

$\frac{1}{4}\left(\arctan(3) - \arctan\left(\frac{1}{2}\right)\right)$ ***A1***

let the integral $= I$

$\tan 4I = \tan\left(\arctan(3) - \arctan\left(\frac{1}{2}\right)\right)$ ***M1***

$\frac{3 - 0.5}{1 + 3 \times 0.5} = \frac{2.5}{2.5} = 1$ ***(M1)A1***

$4I = \frac{\pi}{4} \Rightarrow I = \frac{\pi}{16}$ ***A1AG***

[7 marks]

Total [19 marks]

13. (a) $B\left(6, \frac{2}{3}\right)$ ***(M1)***

$p(4) = \binom{6}{4}\left(\frac{2}{3}\right)^4\left(\frac{1}{3}\right)^2$ ***A1***

$\binom{6}{4} = 15$ ***A1***

$= 15 \times \frac{2^4}{3^6} = \frac{80}{243}$ ***AG***

[3 marks]

(b) (i) 2 outcomes for each of the 6 games or $2^6 = 64$ ***R1***

(ii) $(1+x)^6 = \binom{6}{0} + \binom{6}{1}x + \binom{6}{2}x^2 + \binom{6}{3}x^3 + \binom{6}{4}x^4 + \binom{6}{5}x^5 + \binom{6}{6}x^6$ ***A1***

Note: Accept ${}^nC_r$ notation or $1 + 6x + 15x^2 + 20x^3 + 15x^4 + 6x^5 + x^6$

setting $x = 1$ in both sides of the expression ***R1***

Note: Do not award ***R1*** if the right hand side is not in the correct form.

$64 = \binom{6}{0} + \binom{6}{1} + \binom{6}{2} + \binom{6}{3} + \binom{6}{4} + \binom{6}{5} + \binom{6}{6}$ ***AG***

(iii) the total number of outcomes $=$ number of ways Alfred can win no games, plus the number of ways he can win one game *etc*. ***R1***

[4 marks]

(c) (i) Let $\mathrm{P}(x, y)$ be the probability that Alfred wins x games on the first day and y on the second.

$\mathrm{P}(4, 2) = \binom{6}{4} \times \left(\frac{2}{3}\right)^4 \times \left(\frac{1}{3}\right)^2 \times \binom{6}{2} \times \left(\frac{2}{3}\right)^2 \times \left(\frac{1}{3}\right)^4$ ***M1A1***

$\binom{6}{2}^2\left(\frac{2}{3}\right)^6\left(\frac{1}{3}\right)^6$ or $\binom{6}{4}^2\left(\frac{2}{3}\right)^6\left(\frac{1}{3}\right)^6$ ***A1***

$r = 2$ or 4, $s = t = 6$

continued …

Question 13 continued

(ii) $\mathrm{P}(\text{Total} = 6) =$

$\mathrm{P}(0, 6) + \mathrm{P}(1, 5) + \mathrm{P}(2, 4) + \mathrm{P}(3, 3) + \mathrm{P}(4, 2) + \mathrm{P}(5, 1) + \mathrm{P}(6, 0)$ ***(M1)***

$$= \binom{6}{0}^2 \left(\frac{2}{3}\right)^6 \left(\frac{1}{3}\right)^6 + \binom{6}{1}^2 \left(\frac{2}{3}\right)^6 \left(\frac{1}{3}\right)^6 + \ldots + \binom{6}{6}^2 \left(\frac{2}{3}\right)^6 \left(\frac{1}{3}\right)^6$$ ***A2***

$$= \frac{2^6}{3^{12}} \left(\binom{6}{0}^2 + \binom{6}{1}^2 + \binom{6}{2}^2 + \binom{6}{3}^2 + \binom{6}{4}^2 + \binom{6}{5}^2 + \binom{6}{6}^2 \right)$$

Note: Accept any valid sum of 7 probabilities.

(iii) use of $\binom{6}{i} = \binom{6}{6-i}$ ***(M1)***

(can be used either here or in (c)(ii))

$$\mathrm{P}(\text{wins 6 out of 12}) = \binom{12}{6} \times \left(\frac{2}{3}\right)^6 \times \left(\frac{1}{3}\right)^6 = \frac{2^6}{3^{12}} \binom{12}{6}$$ ***A1***

$$\frac{2^6}{3^{12}} \left(\binom{6}{0}^2 + \binom{6}{1}^2 + \binom{6}{2}^2 + \binom{6}{3}^2 + \binom{6}{4}^2 + \binom{6}{5}^2 + \binom{6}{6}^2 \right) = \frac{2^6}{3^{12}} \binom{12}{6}$$ ***A1***

therefore $\binom{6}{0}^2 + \binom{6}{1}^2 + \binom{6}{2}^2 + \binom{6}{3}^2 + \binom{6}{4}^2 + \binom{6}{5}^2 + \binom{6}{6}^2 = \binom{12}{6}$ ***AG***

[9 marks]

(d) (i) $$\mathrm{E}(A) = \sum_{r=0}^{n} r \binom{n}{r} \left(\frac{2}{3}\right)^r \left(\frac{1}{3}\right)^{n-r} = \sum_{r=0}^{n} r \binom{n}{r} \frac{2^r}{3^n}$$

$(a = 2,\ b = 3)$ ***M1A1***

Note: ***M0A0*** for $a = 2$, $b = 3$ without any method.

(ii) $$n(1+x)^{n-1} = \sum_{r=1}^{n} \binom{n}{r} r x^{r-1}$$ ***A1A1***

(sigma notation not necessary)

(if sigma notation used also allow lower limit to be $r = 0$)

let $x = 2$ ***M1***

$$n3^{n-1} = \sum_{r=1}^{n} \binom{n}{r} r 2^{r-1}$$

multiply by 2 and divide by 3^n ***(M1)***

$$\frac{2n}{3} = \sum_{r=1}^{n} \binom{n}{r} r \frac{2^r}{3^n} \quad \left(= \sum_{r=0}^{n} \binom{n}{r} \frac{2^r}{3^n} \right)$$ ***AG***

[6 marks]