Markscheme

November 2016

Mathematics

Higher level

Paper 2

Instructions to Examiners

Abbreviations

M Marks awarded for attempting to use a valid **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 RM™ Assessor instructions and the document **"Mathematics HL: Guidance for e-marking November 2016"**. 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 RM™ Assessor.

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, for example, ***M1A1***, this usually means ***M1*** for an **attempt** to use an appropriate method (for example, 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 correct working. However, if further working indicates a lack of mathematical understanding do not award the final ***A1***. An exception to this may be in numerical answers, where a correct exact value is followed by an incorrect decimal. However, if the incorrect decimal is carried through to a subsequent part, and correct ***FT*** working shown, award ***FT*** marks as appropriate but do not award the final ***A1*** in that part.

  Examples

	Correct answer seen	**Further working seen**	**Action**
1.	$8\sqrt{2}$	$5.65685...$ *(incorrect decimal value)*	Award the final ***A1*** *(ignore the further working)*
2.	$\frac{1}{4}\sin 4x$	$\sin x$	Do not award the final ***A1***
3.	$\log a - \log b$	$\log(a-b)$	Do not award the final ***A1***

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**, for example, **(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 (for example, $\sin\theta = 1.5$), 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 Misread

*If a candidate incorrectly copies information from the question, this is a misread (**MR**).*
*A candidate should be penalized only once for a particular misread. 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 (for example, $\sin\theta = 1.5$), 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:

  $$f'(x) = \left(2\cos(5x-3)\right)5 \quad \left(= 10\cos(5x-3)\right) \qquad \textbf{\textit{A1}}$$

  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

A GDC is required for paper 2, but calculators with symbolic manipulation features (for example, TI-89) are not allowed.

Calculator notation
The Mathematics HL guide says:

Students must always use correct mathematical notation, not calculator notation.

Do **not** accept final answers written using calculator notation. However, do not penalize the use of calculator notation in the working.

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.

14. Candidate work

Candidates are meant to write their answers to Section A on the question paper (QP), and Section B on answer booklets. Sometimes, they need more room for Section A, and use the booklet (and often comment to this effect on the QP), or write outside the box. This work should be marked.

The instructions tell candidates not to write on Section B of the QP. Thus they may well have done some rough work here which they assume will be ignored. If they have solutions on the answer booklets, there is no need to look at the QP. However, if there are whole questions or whole part solutions missing on answer booklets, please check to make sure that they are not on the QP, and if they are, mark those whole questions or whole part solutions that have not been written on answer booklets.

Section A

1. (a) $\mathrm{E}\left(X^2\right) = \sum x^2 \cdot \mathrm{P}(X = x) = 10.37$ $(= 10.4$ 3 sf) ***(M1)A1***

[2 marks]

(b) **METHOD 1**

$\mathrm{sd}(X) = 1.44069\ldots$ ***(M1)(A1)***

$\mathrm{Var}(X) = 2.08$ $(= 2.0756)$ ***A1***

METHOD 2

$\mathrm{E}(X) = 2.88$ $(= 0.06 + 0.27 + 0.5 + 0.98 + 0.63 + 0.44)$ ***(A1)***

use of $\mathrm{Var}(X) = \mathrm{E}\left(X^2\right) - \left(\mathrm{E}(X)\right)^2$ ***(M1)***

Note: Award ***(M1)*** only if $\left(\mathrm{E}(X)\right)^2$ is used correctly.

$\left(\mathrm{Var}(X) = 10.37 - 8.29\right)$

$\mathrm{Var}(X) = 2.08$ $(= 2.0756)$ ***A1***

Note: Accept 2.11.

METHOD 3

$\mathrm{E}(X) = 2.88$ $(= 0.06 + 0.27 + 0.5 + 0.98 + 0.63 + 0.44)$ ***(A1)***

use of $\mathrm{Var}(X) = \mathrm{E}\left(\left(X - \mathrm{E}(X)\right)^2\right)$ ***(M1)***

$\left(0.679728 + \ldots + 0.549152\right)$

$\mathrm{Var}(X) = 2.08$ $(= 2.0756)$ ***A1***

[3 marks]

Total [5 marks]

2. $\boldsymbol{n}_1 = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$ and $\boldsymbol{n}_2 = \begin{pmatrix} 2 \\ 0 \\ -1 \end{pmatrix}$ ***(A1)(A1)***

EITHER

$\theta = \arccos\left(\frac{\boldsymbol{n}_1 \cdot \boldsymbol{n}_2}{|\boldsymbol{n}_1||\boldsymbol{n}_2|}\right) \quad \left(\cos\theta = \frac{\boldsymbol{n}_1 \cdot \boldsymbol{n}_2}{|\boldsymbol{n}_1||\boldsymbol{n}_2|}\right)$ ***(M1)***

$= \arccos\left(\frac{2+0-1}{\sqrt{3}\sqrt{5}}\right) \quad \left(\cos\theta = \frac{2+0-1}{\sqrt{3}\sqrt{5}}\right)$ ***(A1)***

$= \arccos\left(\frac{1}{\sqrt{15}}\right) \quad \left(\cos\theta = \frac{1}{\sqrt{15}}\right)$

OR

$\theta = \arcsin\left(\frac{|\boldsymbol{n}_1 \times \boldsymbol{n}_2|}{|\boldsymbol{n}_1||\boldsymbol{n}_2|}\right) \quad \left(\sin\theta = \frac{|\boldsymbol{n}_1 \times \boldsymbol{n}_2|}{|\boldsymbol{n}_1||\boldsymbol{n}_2|}\right)$ ***(M1)***

$= \arcsin\left(\frac{\sqrt{14}}{\sqrt{3}\sqrt{5}}\right) \quad \left(\sin\theta = \frac{\sqrt{14}}{\sqrt{3}\sqrt{5}}\right)$ ***(A1)***

$= \arcsin\left(\frac{\sqrt{14}}{\sqrt{15}}\right) \quad \left(\sin\theta = \frac{\sqrt{14}}{\sqrt{15}}\right)$

THEN

$= 75.0^\circ$ (or 1.31) ***A1***

[5 marks]

3. (a) **METHOD 1**

$\mathrm{P}(X = x+1) = \dfrac{\mu^{x+1}}{(x+1)!}\mathrm{e}^{-\mu}$ ***A1***

$= \dfrac{\mu}{x+1} \times \dfrac{\mu^x}{x!}\mathrm{e}^{-\mu}$ ***M1A1***

$= \dfrac{\mu}{x+1} \times \mathrm{P}(X = x)$ ***AG***

METHOD 2

$\dfrac{\mu}{x+1} \times \mathrm{P}(X = x) = \dfrac{\mu}{x+1} \times \dfrac{\mu^x}{x!}\mathrm{e}^{-\mu}$ ***A1***

$= \dfrac{\mu^{x+1}}{(x+1)!}\mathrm{e}^{-\mu}$ ***M1A1***

$= \mathrm{P}(X = x+1)$ ***AG***

METHOD 3

$\dfrac{\mathrm{P}(X = x+1)}{\mathrm{P}(X = x)} = \dfrac{\dfrac{\mu^{x+1}}{(x+1)!}\mathrm{e}^{-\mu}}{\dfrac{\mu^x}{x!}\mathrm{e}^{-\mu}}$ ***(M1)***

$= \dfrac{\mu^{x+1}}{\mu^x} \times \dfrac{x!}{(x+1)!}$ ***A1***

$= \dfrac{\mu}{x+1}$ ***A1***

and so $\mathrm{P}(X = x+1) = \dfrac{\mu}{x+1} \times \mathrm{P}(X = x)$ ***AG***

[3 marks]

(b) $\mathrm{P}(X = 3) = \dfrac{\mu}{3} \cdot \mathrm{P}(X = 2)$ $\left(0.112777 = \dfrac{\mu}{3} \cdot 0.241667\right)$ ***A1***

attempting to solve for μ ***(M1)***

$\mu = 1.40$ ***A1***

[3 marks]

Total [6 marks]

4. attempting a valid method to obtain the required term in the expansion ***(M1)***

Note:	Valid methods include an attempt to expand, noting the behaviour of the powers of x, use of the general binomial expansion term, use of a ratio etc.

identifying the correct term ***(A1)***

$\binom{12}{8} \times 4^4 \times \left(-\frac{3}{2}\right)^8 \quad \left(= 495 \times 4^4 \times \left(-\frac{3}{2}\right)^8\right)$ ***M1A1***

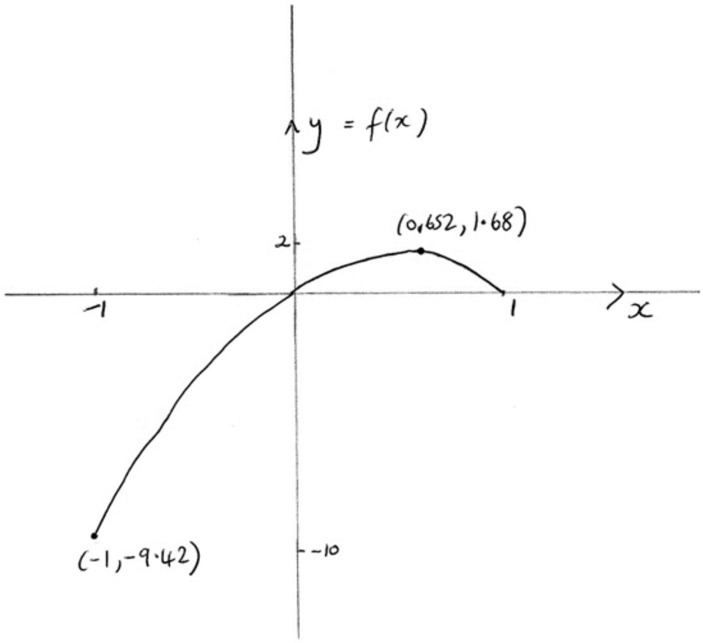
Note:	Accept $\binom{12}{4}$.

Note:	Award ***M1*** for the product of a binomial coefficient, a power of 4 and either a power of $-\frac{3}{2}$ or $\frac{3}{2}$.

$= 3247695$ ***A1***

[5 marks]

5. (a)



correct shape passing through the origin and correct domain ***A1***

Note:	Endpoint coordinates are not required. The domain can be indicated by -1 and 1 marked on the x-axis.

$(0.652, 1.68)$ ***A1***

two correct intercepts (coordinates not required) ***A1***

Note:	A graph passing through the origin is sufficient for $(0, 0)$.

[3 marks]

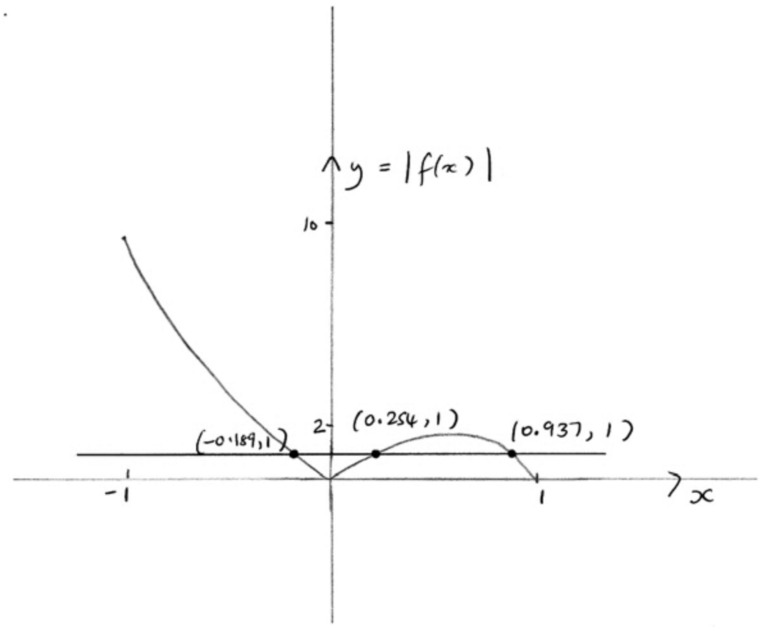
(b) $[-9.42, 1.68]$ (or $[-3\pi, 1.68]$) ***A1A1***

Note:	Award ***A1A0*** for open or semi-open intervals with correct endpoints. Award ***A1A0*** for closed intervals with one correct endpoint.

[2 marks]

continued…

(c) attempting to solve either $\left|3x\arccos(x)\right| > 1$ (or equivalent) or $\left|3x\arccos(x)\right| = 1$ (or equivalent) (*eg*. graphically) ***(M1)***



$x = -0.189,\ 0.254,\ 0.937$ ***(A1)***

$-1 \le x < -0.189$ or $0.254 < x < 0.937$ ***A1A1***

Note: Award ***A0*** for $x < -0.189$.

[4 marks]

Total [9 marks]

6. **METHOD 1**

substituting for x and attempting to solve for y (or vice versa) ***(M1)***

$y = (\pm)\ 0.11821\ldots$ ***(A1)***

EITHER

$145x + 143y\dfrac{dy}{dx} = 0\ \left(\dfrac{dy}{dx} = -\dfrac{145x}{143y}\right)$ ***M1A1***

OR

$145x\dfrac{dx}{dt} + 143y\dfrac{dy}{dt} = 0$ ***M1A1***

THEN

attempting to find $\dfrac{dy}{dt}$ $\left(\dfrac{dy}{dt} = -\dfrac{145\left(3.2\times10^{-3}\right)}{143\left((\pm)\ 0.11821\ldots\right)}\times\left(7.75\times10^{-5}\right)\right)$ ***(M1)***

$\dfrac{dy}{dt} = \pm 2.13\times10^{-6}$ ***A1***

Note: Award all marks except the final ***A1*** to candidates who do not consider $\pm$.

METHOD 2

$y = (\pm)\sqrt{\dfrac{1-72.5x^2}{71.5}}$ ***M1A1***

$\dfrac{dy}{dx} = (\pm)0.0274\ldots$ ***(M1)(A1)***

$\dfrac{dy}{dt} = (\pm)0.0274\ldots\times7.75\times10^{-5}$ ***(M1)***

$\dfrac{dy}{dt} = \pm 2.13\times10^{-6}$ ***A1***

Note: Award all marks except the final ***A1*** to candidates who do not consider $\pm$.

[6 marks]

7. (a) **METHOD 1**

let $\mathrm{AC} = x$

$3^2 = x^2 + 4^2 - 8x\cos\frac{\pi}{9}$ ***M1A1***

attempting to solve for x ***(M1)***

$x = 1.09,\ 6.43$ ***A1A1***

METHOD 2

let $\mathrm{AC} = x$

using the sine rule to find a value of C ***M1***

$4^2 = x^2 + 3^2 - 6x\cos(152.869\ldots°) \Rightarrow x = 1.09$ ***(M1)A1***

$4^2 = x^2 + 3^2 - 6x\cos(27.131\ldots°) \Rightarrow x = 6.43$ ***(M1)A1***

METHOD 3

let $\mathrm{AC} = x$

using the sine rule to find a value of B and a value of C ***M1***

obtaining $B = 132.869\ldots°,\ 7.131\ldots°$ and $C = 27.131\ldots°,\ 152.869\ldots°$ ***A1***

($B = 2.319\ldots,\ 0.124\ldots$ and $C = 0.473\ldots,\ 2.668\ldots$)

attempting to find a value of x using the cosine rule ***(M1)***

$x = 1.09,\ 6.43$ ***A1A1***

Note: Award ***M1A0(M1)A1A0*** for one correct value of x

[5 marks]

(b) $\frac{1}{2}\times 4\times 6.428\ldots\times\sin\frac{\pi}{9}$ and $\frac{1}{2}\times 4\times 1.088\ldots\times\sin\frac{\pi}{9}$ ***(A1)***

($4.39747\ldots$ and $0.744833\ldots$)

let D be the difference between the two areas

$D = \frac{1}{2}\times 4\times 6.428\ldots\times\sin\frac{\pi}{9} - \frac{1}{2}\times 4\times 1.088\ldots\times\sin\frac{\pi}{9}$ ***(M1)***

$(D = 4.39747\ldots - 0.744833\ldots)$

$= 3.65\left(\mathrm{cm}^2\right)$ ***A1***

[3 marks]

Total [8 marks]

8. (a) $\mathrm{P}(X < 42.52) = 0.6940$ ***(M1)***

either $\mathrm{P}\left(Z < \frac{30.31-\mu}{\sigma}\right) = 0.1180$ or $\mathrm{P}\left(Z < \frac{42.52-\mu}{\sigma}\right) = 0.6940$ ***(M1)***

$\frac{30.31-\mu}{\sigma} = \underbrace{\Phi^{-1}(0.1180)}_{-1.1850\ldots}$ ***(A1)***

$\frac{42.52-\mu}{\sigma} = \underbrace{\Phi^{-1}(0.6940)}_{0.5072\ldots}$ ***(A1)***

attempting to solve simultaneously ***(M1)***

$\mu = 38.9$ and $\sigma = 7.22$ ***A1***

[6 marks]

(b) $\mathrm{P}(\mu - 1.2\sigma < X < \mu + 1.2\sigma)$ (or equivalent *eg*. $2\mathrm{P}(\mu < X < \mu + 1.2\sigma)$) ***(M1)***

$= 0.770$ ***A1***

Note: Award ***(M1)A1*** for $\mathrm{P}(-1.2 < Z < 1.2) = 0.770$.

[2 marks]

Total [8 marks]

9. (a) $A = 2(\alpha - \sin\alpha)r^2 + \frac{1}{2}(\theta - \sin\theta)r^2$ ***M1A1A1***

Note: Award ***M1A1A1*** for alternative correct expressions *eg*. $A = 4\left(\frac{\alpha}{2} - \sin\frac{\alpha}{2}\right)r^2 + \frac{1}{2}\theta r^2$.

[3 marks]

(b) **METHOD 1**

consider for example triangle ADM where M is the midpoint of BD ***M1***

$\sin\frac{\alpha}{4} = \frac{1}{4}$ ***A1***

$\frac{\alpha}{4} = \arcsin\frac{1}{4}$

$\alpha = 4\arcsin\frac{1}{4}$ ***AG***

METHOD 2

attempting to use the cosine rule (to obtain $1 - \cos\frac{\alpha}{2} = \frac{1}{8}$) ***M1***

$\sin\frac{\alpha}{4} = \frac{1}{4}$ (obtained from $\sin\frac{\alpha}{4} = \sqrt{\frac{1-\cos\frac{\alpha}{2}}{2}}$) ***A1***

$\frac{\alpha}{4} = \arcsin\frac{1}{4}$

$\alpha = 4\arcsin\frac{1}{4}$ ***AG***

METHOD 3

$\sin\left(\frac{\pi}{2} - \frac{\alpha}{4}\right) = 2\sin\frac{\alpha}{2}$ where $\frac{\theta}{2} = \frac{\pi}{2} - \frac{\alpha}{4}$

$\cos\frac{\alpha}{4} = 4\sin\frac{\alpha}{4}\cos\frac{\alpha}{4}$ ***M1***

Note: Award ***M1*** either for use of the double angle formula or the conversion from sine to cosine.

$\frac{1}{4} = \sin\frac{\alpha}{4}$ ***A1***

$\frac{\alpha}{4} = \arcsin\frac{1}{4}$

$\alpha = 4\arcsin\frac{1}{4}$ ***AG***

[2 marks]

continued…

Question 9 continued

(c) (from triangle ADM), $\theta = \pi - \dfrac{\alpha}{2}$ $\left(= \pi - 2\arcsin\dfrac{1}{4} = 2\arccos\dfrac{1}{4} = 2.6362\ldots\right)$ ***A1***

attempting to solve $2(\alpha - \sin\alpha)r^2 + \dfrac{1}{2}(\theta - \sin\theta)r^2 = 4$

with $\alpha = 4\arcsin\dfrac{1}{4}$ and $\theta = \pi - \dfrac{\alpha}{2}$ $\left(= 2\arccos\dfrac{1}{4}\right)$ for r ***(M1)***

$r = 1.69$ ***A1***

[3 marks]

Total [8 marks]

Section B

10. (a) attempting to solve either $2e^x - 1 = 0$ or $2e^x - 1 \neq 0$ for x ***(M1)***

$D = \mathbb{R} \setminus \{-\ln 2\}$ (or equivalent *eg* $x \neq -\ln 2$) ***A1***

Note: Accept $D = \mathbb{R} \setminus \{-0.693\}$ or equivalent *eg* $x \neq -0.693$.

[2 marks]

(b) considering $\lim\limits_{x \to -\ln 2} f(x)$ ***(M1)***

$x = -\ln 2$ $\left(x = -0.693\right)$ ***A1***

considering one of $\lim\limits_{x \to -\infty} f(x)$ or $\lim\limits_{x \to +\infty} f(x)$ ***M1***

$\lim\limits_{x \to -\infty} f(x) = -2 \Rightarrow y = -2$ ***A1***

$\lim\limits_{x \to +\infty} f(x) = -\frac{1}{2} \Rightarrow y = -\frac{1}{2}$ ***A1***

Note: Award ***A0A0*** for $y = -2$ and $y = -\frac{1}{2}$ stated without any justification.

[5 marks]

(c) $f'(x) = \dfrac{-e^x\left(2e^x - 1\right) - 2e^x\left(2 - e^x\right)}{\left(2e^x - 1\right)^2}$ ***M1A1A1***

$= -\dfrac{3e^x}{\left(2e^x - 1\right)^2}$ ***AG***

[3 marks]

(d) $f'(x) < 0$ (for all $x \in D$) $\Rightarrow$ f is (strictly) decreasing ***R1***

Note: Award ***R1*** for a statement such as $f'(x) \neq 0$ and so the graph of f has no turning points.

one branch is above the upper horizontal asymptote and the other branch is below the lower horizontal asymptote ***R1***

f has an inverse ***AG***

$-\infty < x < -2 \cup -\frac{1}{2} < x < \infty$ ***A2***

Note: Award ***A2*** if the domain of the inverse is seen in either part (d) or in part (e).

[4 marks]

continued…

Question 10 continued

(e) $x = \dfrac{2 - e^y}{2e^y - 1}$ ***M1***

Note: Award ***M1*** for interchanging x and y (can be done at a later stage).

$2xe^y - x = 2 - e^y$ ***M1***

$e^y(2x + 1) = x + 2$ ***A1***

$f^{-1}(x) = \ln\left(\dfrac{x+2}{2x+1}\right)$ $\left(f^{-1}(x) = \ln(x+2) - \ln(2x+1)\right)$ ***A1***

[4 marks]

(f) use of $V = \pi\int_a^b x^2\,dy$ ***(M1)***

$= \pi\int_0^1 \left(\ln\left(\dfrac{y+2}{2y+1}\right)\right)^2 dy$ ***(A1)(A1)***

Note: Award ***(A1)*** for the correct integrand and ***(A1)*** for the limits.

$= 0.331$ ***A1***

[4 marks]

Total [22 marks]

11. (a) $\mathrm{P}(X=3)=(0.1)^3$ ***A1***

$=0.001$ ***AG***

$\mathrm{P}(X=4)=\mathrm{P}\left(VV\overline{V}V\right)+\mathrm{P}\left(V\overline{V}VV\right)+\mathrm{P}\left(\overline{V}VVV\right)$ ***(M1)***

$=3\times(0.1)^3\times 0.9$ (or equivalent) ***A1***

$=0.0027$ ***AG***

[3 marks]

(b) **METHOD 1**

attempting to form equations in a and b ***M1***

$\dfrac{9+3a+b}{2000}=\dfrac{1}{1000}\quad(3a+b=-7)$ ***A1***

$\dfrac{16+4a+b}{2000}\times\dfrac{9}{10}=\dfrac{27}{10000}\quad(4a+b=-10)$ ***A1***

attempting to solve simultaneously ***(M1)***

$a=-3,\ b=2$ ***A1***

METHOD 2

$\mathrm{P}(X=n)=\begin{pmatrix}n-1\\2\end{pmatrix}\times 0.1^3\times 0.9^{n-3}$ ***M1***

$=\dfrac{(n-1)(n-2)}{2000}\times 0.9^{n-3}$ ***(M1)A1***

$=\dfrac{n^2-3n+2}{2000}\times 0.9^{n-3}$ ***A1***

$a=-3,\ b=2$ ***A1***

Note: Condone the absence of 0.9^{n-3} in the determination of the values of a and b.

[5 marks]

continued…

(c) **METHOD 1**

EITHER

$$\mathrm{P}(X = n) = \frac{n^2 - 3n + 2}{2000} \times 0.9^{n-3}$$ ***(M1)***

OR

$$\mathrm{P}(X = n) = \binom{n-1}{2} \times 0.1^3 \times 0.9^{n-3}$$ ***(M1)***

THEN

$$= \frac{(n-1)(n-2)}{2000} \times 0.9^{n-3}$$ ***A1***

$$\mathrm{P}(X = n-1) = \frac{(n-2)(n-3)}{2000} \times 0.9^{n-4}$$ ***A1***

$$\frac{\mathrm{P}(X = n)}{\mathrm{P}(X = n-1)} = \frac{(n-1)(n-2)}{(n-2)(n-3)} \times 0.9$$ ***A1***

$$= \frac{0.9(n-1)}{n-3}$$ ***AG***

METHOD 2

$$\frac{\mathrm{P}(X = n)}{\mathrm{P}(X = n-1)} = \frac{\dfrac{n^2 - 3n + 2}{2000} \times 0.9^{n-3}}{\dfrac{(n-1)^2 - 3(n-1) + 2}{2000} \times 0.9^{n-4}}$$ ***(M1)***

$$= \frac{0.9\left(n^2 - 3n + 2\right)}{\left(n^2 - 5n + 6\right)}$$ ***A1A1***

Note: Award ***A1*** for a correct numerator and ***A1*** for a correct denominator.

$$= \frac{0.9(n-1)(n-2)}{(n-2)(n-3)}$$ ***A1***

$$= \frac{0.9(n-1)}{n-3}$$ ***AG***

[4 marks]

continued…

Question 11 continued

(d) (i) attempting to solve $\frac{0.9(n-1)}{n-3}=1$ for n ***M1***

$n=21$ ***A1***

$\frac{0.9(n-1)}{n-3}<1 \Rightarrow n>21$ ***R1***

$\frac{0.9(n-1)}{n-3}>1 \Rightarrow n<21$ ***R1***

X has two modes ***AG***

Note: Award ***R1R1*** for a clearly labelled graphical representation of the two inequalities (using $\frac{\mathrm{P}(X=n)}{\mathrm{P}(X=n-1)}$).

(ii) the modes are 20 and 21 ***A1***

[5 marks]

(e) **METHOD 1**

$Y \sim \mathrm{B}(x, 0.1)$ ***(A1)***

attempting to solve $\mathrm{P}(Y \geq 3)>0.5$ (or equivalent *eg* $1-\mathrm{P}(Y \leq 2)>0.5$) for x ***(M1)***

Note: Award ***(M1)*** for attempting to solve an equality (obtaining $x=26.4$).

$x=27$ ***A1***

METHOD 2

$\sum_{n=0}^{x} \mathrm{P}(X=n)>0.5$ ***(A1)***

attempting to solve for x ***(M1)***

$x=27$ ***A1***

[3 marks]

Total [20 marks]

12. (a) $A_1 = 1.004x$ ***A1***

$A_2 = 1.004(1.004x + x)$ ***A1***

$= 1.004^2 x + 1.004x$ ***AG***

Note: Accept an argument in words for example, first deposit has been in for two months and second deposit has been in for one month.

[2 marks]

(b) (i) $A_3 = 1.004\left(1.004^2 x + 1.004x + x\right) = 1.004^3 x + 1.004^2 x + 1.004x$ ***(M1)A1***

$A_4 = 1.004^4 x + 1.004^3 x + 1.004^2 x + 1.004x$ ***A1***

(ii) $A_{120} = \left(1.004^{120} + 1.004^{119} + \ldots + 1.004\right)x$ ***(A1)***

$$= \frac{1.004^{120} - 1}{1.004 - 1} \times 1.004x$$ ***M1A1***

$= 251\left(1.004^{120} - 1\right)x$ ***AG***

[6 marks]

(c) $A_{216} = 251\left(1.004^{216} - 1\right)x \quad \left(= x\sum_{t=1}^{216} 1.004^t\right)$ ***A1***

[1 mark]

(d) $251\left(1.004^{216} - 1\right)x = 20000 \Rightarrow x = 58.22\ldots$ ***(A1)(M1)(A1)***

Note: Award ***(A1)*** for $251\left(1.004^{216} - 1\right)x > 20000$, ***(M1)*** for attempting to solve and ***(A1)*** for $x > 58.22\ldots$.

$x = 59$ ***A1***

Note: Accept $x = 58$. Accept $x \geq 59$.

[4 marks]

(e) $r = 1.004^{12}$ $(= 1.049\ldots)$ ***(M1)***

$15000\,r^n - 1000\,\dfrac{r^n - 1}{r - 1} = 0 \Rightarrow n = 27.8\ldots$ ***(A1)(M1)(A1)***

Note: Award ***(A1)*** for the equation (with their value of r), ***(M1)*** for attempting to solve for n and ***(A1)*** for $n = 27.8\ldots$.

$n = 28$ ***A1***

Note: Accept $n = 27$.

[5 marks]

Total [18 marks]