Markscheme

May 2022

Mathematics: applications and interpretation

Higher level

Paper 1

23 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.	$\frac{35}{72}$	$0.468111\ldots$ (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 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) 1.2 metres ***A1***

[1 mark]

(b) $-4.8t^2 + 21t + 1.2 = 0$ ***(M1)***

$(t =)$ 4.43 s $(4.431415...\ s)$ ***A1***

> **Note:** If both values for t are seen do not award the ***A1*** mark unless the negative is explicitly excluded.

[2 marks]

(c) $0 \le t \le 4.43$ **OR** $[0,\ 4.43]$ ***A1A1***

> **Note:** Award ***A1*** for correct endpoints and ***A1*** for expressing answer with correct notation. Award at most ***A1A0*** for use of x instead of t.

[2 marks]
[Total 5 marks]

2. (a) $x + y + z = 600$ ***A1***

$15x + 10y + 12z = 7816$ ***A1***

$x = 2y$ ***A1***

> **Note:** Condone other labelling if clear, e.g. a (adult), c (child) and s (student). Accept equivalent, distinct equations e.g. $2y + y + z = 600$.

[3 marks]

(b) $x = 308,\ y = 154,\ z = 138$ ***A1A1***

> **Note:** Award ***A1*** for all three correct values seen, ***A1*** for correctly labelled as x, y or z. Accept answers written in words: e.g. 308 adult tickets.

[2 marks]
[Total 5 marks]

3. (a) H_0: The die is fair **OR** $P(\text{any number}) = \frac{1}{6}$ **OR** probabilities are equal

H_1: The die is not fair **OR** $P(\text{any number}) \neq \frac{1}{6}$ **OR** probabilities are not equal ***A1***

[1 mark]

(b) 5 ***A1***

[1 mark]

(c) 10 ***A1***

[1 mark]

(d) (p-value =) 0.287 $(0.28724163\ldots.)$ ***A2***

[2 marks]

(e) $0.287 > 0.05$ ***R1***

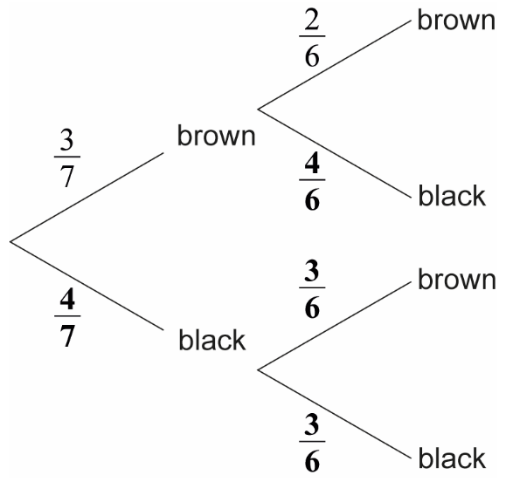
EITHER
Insufficient evidence to reject the null hypothesis ***A1***

OR
Insufficient evidence to reject that the die is fair ***A1***

Note: Do not award ***R0A1***. Condone "*accept* the null hypothesis" or "the die is fair". Their conclusion must be consistent with their p-value and their hypothesis.

[2 marks]
[Total 7 marks]

4. (a)



A1A1

Note: Award ***A1*** for $\frac{4}{7}$ and $\frac{4}{6}$ correctly placed, ***A1*** for final two probabilities correct.

[2 marks]

(b) multiplying along branches and then adding outcomes ***(M1)***

$$\frac{3}{7}\times\frac{2}{6}+\frac{4}{7}\times\frac{3}{6}$$

$$=\frac{18}{42}\left(=\frac{3}{7}\approx 0.429\ (42.9\%)\right)$$ ***A1***

[2 marks]

(c) use of conditional probability formula ***M1***

$$\frac{\left(\frac{3}{7}\times\frac{2}{6}\right)}{\left(\frac{3}{7}\right)}$$ ***A1***

$$=\frac{6}{18}\left(=\frac{1}{3}\right)\ \left(\frac{252}{756},\ 0.333,\ 33.3\%\right)$$ ***A1***

[3 marks]
[Total 7 marks]

5. (a) use of geometric sequence with $r = 0.85$ ***M1***

EITHER

$(0.85)^6(1.8)$ **OR** $0.678869\ldots$ **OR** $(0.85)^5(1.53)$ ***A1***

$= 0.68 \text{ m}$

$= 68 \text{ cm}$ ***AG***

OR

$(0.85)^6(180)$ **OR** $(0.85)^5(153)$ ***A1***

$= 68 \text{ cm}$ ***AG***

[2 marks]

(b) **EITHER**

$(0.85)^n(1.8) > 0.1$ **OR** $(0.85)^{n-1}(1.53) > 0.1$ ***(M1)***

Note: If 1.8 m (or 180 cm) is used then ***(M1)*** only awarded for use of n in $(0.85)^n(1.8) > 0.1$.
If 1.53 m (or 153 cm) is used then ***(M1)*** only awarded for use of $n-1$ in $(0.85)^{n-1}(1.53) > 0.1$.

17 ***A1***

OR

$(0.85)^{17}(1.8) = 0.114 \text{ m}$ and $(0.85)^{18}(1.8) = 0.0966 \text{ m}$ ***(M1)***

17 ***A1***

OR

solving $(0.85)^n(1.8) = 0.1$ to find $n = 17.8$ ***(M1)***

17 ***A1***

Note: Evidence of solving may be a graph **OR** the "solver" function **OR** use of logs to solve the equation. Working may use cm.

[2 marks]

continued…

Question 5 continued

(c) **EITHER**

distance (in one direction) travelled between first and fourth bounce

$= \frac{(1.8 \times 0.85)(1-0.85^3)}{1-0.85} \ (= 3.935925)$ ***(A1)***

recognizing distances are travelled twice except first distance ***(M1)***

$1.8 + 2(3.935925)$

$= 9.67 \text{ m} \ (9.67185... \text{ m})$ ***A1***

OR

distance (in one direction) travelled between drop and fourth bounce

$= \frac{(1.8)(1-0.85^4)}{1-0.85} \ (= 5.735925)$ ***(A1)***

recognizing distances are travelled twice except first distance ***(M1)***

$2(5.735925) - 1.8$

$= 9.67 \text{ m} \ (9.67185... \text{ m})$ ***A1***

OR

distance (in one direction) travelled between first and fourth bounce

$(0.85)(1.8) + (0.85)^2(1.8) + (0.85)^3(1.8) \quad (= 3.935925...)$ ***(A1)***

recognizing distances are travelled twice except first distance ***(M1)***

$1.8 + 2(0.85)(1.8) + 2(0.85)^2(1.8) + 2(0.85)^3(1.8)$

$= 9.67 \text{ m} \ (9.67185... \text{ m})$ ***A1***

Note: Answers may be given in cm.

[3 marks]
[Total 7 marks]

6. (a) $\begin{pmatrix} -3.2 \\ -4.5 \\ 6.1 \end{pmatrix}$ ***A1***

[1 mark]

(b) $\sqrt{(-3.2)^2 + (-4.5)^2 + 6.1^2}$ ***(M1)***

$8.22800\ldots \approx 8.23 \text{ m}$ ***A1***

[2 marks]

(c) **EITHER**

$\vec{AO} = \begin{pmatrix} -3.2 \\ -4.5 \\ 0.3 \end{pmatrix}$ ***A1***

$$\cos\theta = \frac{\vec{AO} \bullet \vec{AF}}{\left|\vec{AO}\right|\left|\vec{AF}\right|}$$

$\vec{AO} \bullet \vec{AF} = (-3.2)^2 + (-4.5)^2 + (0.3 \times 6.1) \ (= 32.32)$ ***(A1)***

$\cos\theta = \dfrac{32.32}{\sqrt{3.2^2 + 4.5^2 + 0.3^2} \times 8.22800...}$ ***(M1)***

$= 0.710326\ldots$ ***(A1)***

> **Note:** If $\vec{OA}$ is used in place of $\vec{AO}$ then $\cos\theta$ will be negative.
> Award ***A1(A1)(M1)(A1)*** as above. In order to award the final ***A1***, some justification for changing the resulting obtuse angle to its supplementary angle **must** be seen.

OR

$\text{AO} = \sqrt{3.2^2 + 4.5^2 + 0.3^2} \ (= 5.52991...)$ ***(A1)***

$\cos\theta = \dfrac{8.22800...^2 + 5.52991...^2 - 5.8^2}{2 \times 8.22800... \times 5.52991...}$ ***(M1)(A1)***

$= 0.710326\ldots$ ***(A1)***

THEN

$\theta = 0.780833... \approx 0.781$ **OR** $44.7384\ldots^\circ \approx 44.7^\circ$ ***A1***

[5 marks]

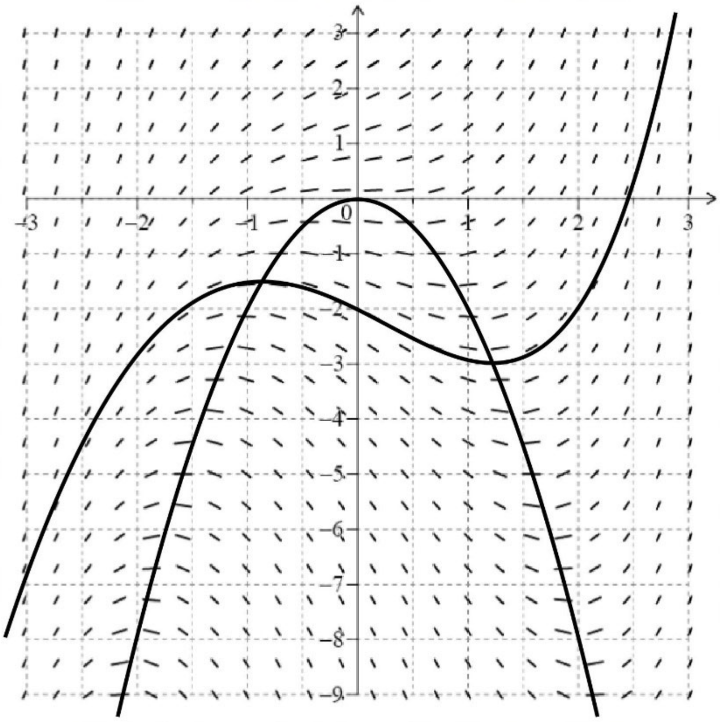
[Total 8 marks]

7. (a) (i) $x^2 + \frac{y}{2} = 0$ $(y = -2x^2)$ ***A1***

(ii) $y = -2x^2$ drawn on diagram (correct shape with a maximum at $(0,\ 0)$) ***A1***

[2 marks]

(b)



correct shape with a local maximum and minimum, passing through $(0,\ -2)$ ***A1***

local maximum and minimum on the graph of $y = -2x^2$ ***A1***

[2 marks]

[Total 4 marks]

8. (a) (i) use of product rule *(M1)*

$$\frac{dy}{dx} = 2\left(4 - e^x\right) + 2x\left(-e^x\right)$$ *A1*

$$= 8 - 2e^x - 2xe^x$$

(ii) use of product rule *(M1)*

$$\frac{d^2y}{dx^2} = -2e^x - 2e^x - 2xe^x$$ *A1*

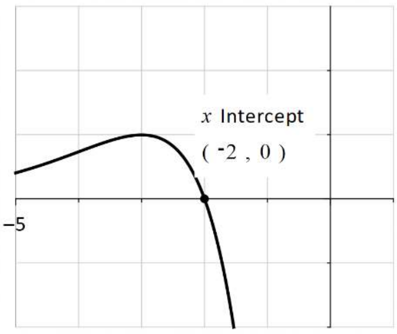
$$= -4e^x - 2xe^x$$

$$= -2(2 + x)e^x$$

[4 marks]

(b) $-2(2 + a)e^a = 0$ **OR** sketch of $\frac{d^2y}{dx^2}$ with x-intercept indicated

OR finding the local maximum of $\frac{dy}{dx}$ at $(-2, 8.27)$ *(M1)*



$(a =)\ -2$ *A1*

[2 marks]
[Total 6 marks]

9. (a) let X be the weight of sugar in the bag

$\mathrm{P}(X < 950) = 0.308537... \approx 0.309$ ***(M1)A1***

[2 marks]

(b) **METHOD 1**

let $\bar{X}$ be the mean weight of 5 bags of sugar

$\mathrm{E}(\bar{X}) = 1000$ ***(A1)***

use of $\mathrm{Var}(\bar{X}) = \frac{\sigma^2}{n}$ ***(M1)***

$\mathrm{Var}(\bar{X}) = \frac{100^2}{5}$ $(= 2000)$ ***(A1)***

$\bar{X} \sim \mathrm{N}(1000, 2000)$

$\mathrm{P}(\bar{X} > 950) = 0.868223... \approx 0.868$ (86.8%) ***A1***

METHOD 2

let T be the total weight of 5 bags of sugar

$\mathrm{E}(T) = 5000$ ***(A1)***

use of $\mathrm{Var}(X_1 + X_2) = \mathrm{Var}(X_1) + \mathrm{Var}(X_2)$ for independent random variables ***(M1)***

$\mathrm{Var}(T) = 5 \times 100^2$ $(= 50\,000)$ ***(A1)***

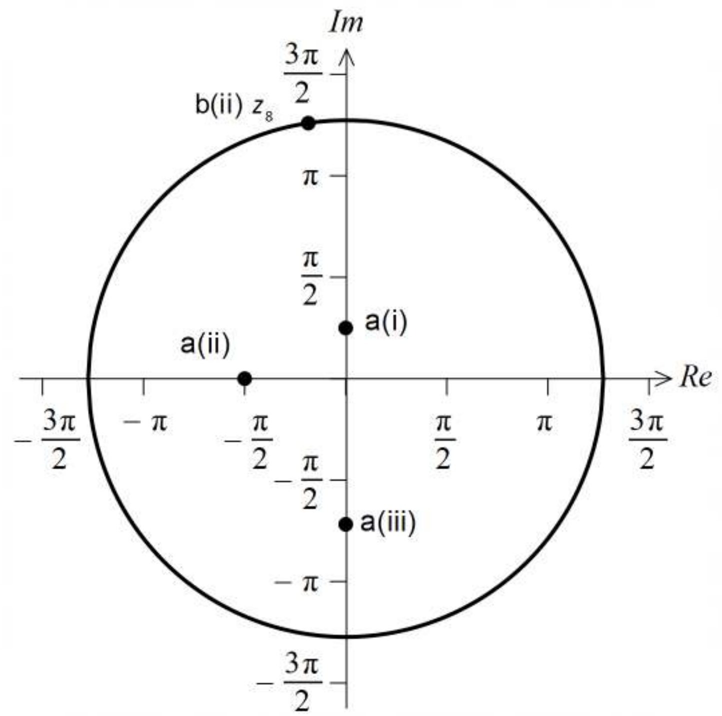
$T \sim \mathrm{N}(5000, 50\,000)$

$\mathrm{P}(T > 4750) = 0.868223... \approx 0.868$ (86.8%) ***A1***

[4 marks]

[Total 6 marks]

10. (a)



A1A1A1

Note:	Award ***A1*** for correct modulus and ***A1*** for correct argument for part (a)(i), and ***A1*** for other two points correct. The points may not be labelled, and they may be shown by line segments.

[3 marks]

(b) (i) $\frac{1}{2}\theta = 4$ ***(M1)***

$\Rightarrow \theta = 8$ ***A1***

(ii) z_8 is shown in the diagram above ***A1A1***

Note:	Award ***A1*** for a point plotted on the circle and ***A1*** for a point plotted in the second quadrant.

[4 marks]
[Total 7 marks]

11. (a) $\lambda = 1$

$\begin{pmatrix} -0.8 & 0.7 \\ 0.8 & -0.7 \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$ **OR** $\begin{pmatrix} 0.2 & 0.7 \\ 0.8 & 0.3 \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix}$ ***(M1)***

$0.8x = 0.7y$ ***(A1)***

an eigenvector is $\begin{pmatrix} 7 \\ 8 \end{pmatrix}$ (or equivalent with integer values) ***A1***

[3 marks]

(b) **EITHER**

(the long-term probability matrix is given by the eigenvector corresponding to the eigenvalue equal to 1, scaled so that the sum of the entries is 1)

$8 + 7 = 15$ ***(M1)***

OR

$\begin{pmatrix} 0.2 & 0.7 \\ 0.8 & 0.3 \end{pmatrix}\begin{pmatrix} p \\ 1-p \end{pmatrix} = \begin{pmatrix} p \\ 1-p \end{pmatrix}$ ***(M1)***

OR

considering high powers of the matrix *e.g.* $\begin{pmatrix} 0.2 & 0.7 \\ 0.8 & 0.3 \end{pmatrix}^{50}$ ***(M1)***

$\begin{pmatrix} \frac{7}{15} & \frac{7}{15} \\ \frac{8}{15} & \frac{8}{15} \end{pmatrix}$

THEN

probability of being in state A is $\frac{7}{15}$ ***A1***

[2 marks]

[Total 5 marks]

12. (a) $\log_{10} 100 = a - 3$ ***(M1)***

$a = 5$ ***A1***

[2 marks]

(b) **EITHER**

$N = 10^{5-M}$ ***(M1)***

$= \frac{10^5}{10^M} \left(= \frac{100000}{10^M} \right)$

OR

$100 = \frac{b}{10^3}$ ***(M1)***

THEN

$b = 100000 \ \ (= 10^5)$ ***A1***

[2 marks]

(c) $N = \frac{10^5}{10^{7.2}} = 0.00631 \ \ (0.0063095...)$ ***A1***

> **Note:** Do not accept an answer of $10^{-2.2}$.

[1 mark]

(d) **METHOD 1**

$Y > 100 \Rightarrow$ no earthquakes in the first 100 years ***(M1)***

EITHER

let X be the number of earthquakes of at least magnitude 7.2 in a year

$X \sim \mathrm{Po}(0.0063095\ldots)$

$(\mathrm{P}(X = 0))^{100}$ ***(M1)***

OR

let X be the number of earthquakes in 100 years

$X \sim \mathrm{Po}(0.0063095\ldots \times 100)$ ***(M1)***

$\mathrm{P}(X = 0)$

THEN

$0.532 \ (0.532082\ldots)$ ***A1***

METHOD 2

$Y > 100 \Rightarrow$ no earthquakes in the first 100 years ***(M1)***

let X be the number of earthquakes in 100 years

since n is large and p is small

$X \sim \mathrm{B}(100, \ 0.0063095\ldots)$ ***(M1)***

$\mathrm{P}(X = 0)$

$0.531 \ \ (0.531019\ldots)$ ***A1***

[3 marks]

[Total 8 marks]

13. (a) $(\boldsymbol{r} =) \begin{pmatrix} 1 \\ 4 \end{pmatrix} + t \begin{pmatrix} 1.2 \\ -0.6 \end{pmatrix}$ ***A1***

Note: Do not condone the use of λ or any other variable apart from t.

[1 mark]

(b) when the bearing from the port is 045°, the distance east from the port is equal to the distance north from the port ***(M1)***

$1 + 1.2t = 4 - 0.6t$ ***(A1)***
$1.8t = 3$

$t = \frac{5}{3}$ $(1.6666\ldots,\ 1$ hour 40 minutes$)$ ***(A1)***

time is $2{:}40$ pm $(14{:}40)$ ***A1***

[4 marks]
[Total 5 marks]

14. (a) (i) $\frac{1}{u^2} + \frac{2}{u} + 1$ ***A1***

(ii) $\int \left(\frac{1}{(x+2)} + 1 \right)^2 \mathrm{d}x$

$= \int \left(\frac{1}{(x+2)^2} + \frac{2}{x+2} + 1 \right) \mathrm{d}x$ **OR** $\int \left(\frac{1}{u^2} + \frac{2}{u} + 1 \right) \mathrm{d}u$ ***(M1)***

$= -\frac{1}{(x+2)} + 2\ln\left| x+2 \right| + x\,(+c)$ ***A1A1***

Note: Award ***A1*** for first expression, ***A1*** for second two expressions. Award ***A1A0*** for a final answer of $= -\frac{1}{u} + 2\ln(u) + u\,(+c)$.

[4 marks]

continued…

Question 14 continued

(b) volume $= \pi\left[-\frac{1}{(x+2)} + 2\ln(x+2) + x\right]_0^2$ **M1**

$= \pi\left(-\frac{1}{4} + 2\ln(4) + 2 + \frac{1}{2} - 2\ln 2\right)$ **A1**

$= \pi\left(\frac{9}{4} + 2\ln(4) - 2\ln 2\right)$

use of log laws seen, for example **M1**

$\pi\left(\frac{9}{4} + 4\ln(2) - 2\ln 2\right)$ **OR** $\pi\left(\frac{9}{4} + 2\ln\left(\frac{4}{2}\right)\right)$

$= \frac{\pi}{4}(9 + 8\ln(2))$ **OR** $a = 9$, $b = 8$ and $c = 2$ **A1**

Note: Other correct integer solutions are possible and should be accepted for example $a = 9$, $b = c = 4$.

[4 marks]
Total [8 marks]

15. (a) $X \sim \mathrm{Po}(324)$ **A1**

Note: Both distribution and mean must be seen for ***A1*** to be awarded.

[1 mark]

(b) $\mathrm{P}(X \le 300)$ ***(M1)***
$= 0.0946831... \approx 0.0947$ **A1**

[2 marks]

(c) (mean number of cars =) $4.5 \times 60 = 270$ ***(A1)***
$\mathrm{P}(X > 300 \mid \lambda = 270)$ ***(M1)***

Note: Award ***M1*** for using $\lambda = 270$ to evaluate a probability.

$\mathrm{P}(X \ge 301)$ **OR** $1 - \mathrm{P}(X \le 300)$ ***(M1)***
$= 0.0334207... \approx 0.0334$ **A1**

[4 marks]
[Total 7 marks]

16. (a) use of power rule *(M1)*

$\frac{dW}{dv} = -1.1848 v^{-0.84}$ **OR** $-1.18 v^{-0.84}$ *A1*

[2 marks]

(b) $\frac{dv}{dt} = 5$ *(A1)*

$\frac{dW}{dt} = \frac{dv}{dt} \times \frac{dW}{dv}$ *(M1)*

$\left(\frac{dW}{dt} = -5 \times 1.1848 v^{-0.84}\right)$

when $v = 10$

$\frac{dW}{dt} = -5 \times 1.1848 \times 10^{-0.84}$ *(M1)*

$-0.856 \ (-0.856278\ldots)\ ^{\circ}\text{C min}^{-1}$ *A2*

Note: Accept a negative answer communicated in words, "decreasing at a rate of…".
Accept a final answer of $-0.852809\ldots\ ^{\circ}\text{C min}^{-1}$ from use of -1.18.
Accept 51.4 (or 51.2) $^{\circ}\text{C hour}^{-1}$.

[5 marks]
[Total 7 marks]

17. substitute coordinates of A

$f(0) = p\,\mathrm{e}^{q\cos(0)} = 6.5$

$6.5 = p\,\mathrm{e}^{q}$ ***(A1)***

substitute coordinates of B

$f(5.2) = p\mathrm{e}^{q\cos(5.2r)} = 0.2$

EITHER

$f'(t) = -pqr\sin(rt)\,\mathrm{e}^{q\cos(rt)}$ ***(M1)***

minimum occurs when $-pqr\sin(5.2r)\,\mathrm{e}^{q\cos(5.2r)} = 0$

$\sin(rt) = 0$

$r \times 5.2 = \pi$ ***(A1)***

OR

minimum value occurs when $\cos(rt) = -1$ ***(M1)***

$r \times 5.2 = \pi$ ***(A1)***

OR

period = $2 \times 5.2 = 10.4$ ***(A1)***

$r = \dfrac{2\pi}{10.4}$ ***(M1)***

THEN

$r = \dfrac{\pi}{5.2} = 0.604152...\ (0.604)$ ***A1***

$0.2 = p\,\mathrm{e}^{-q}$ ***(A1)***

eliminate p or q ***(M1)***

$\mathrm{e}^{2q} = \dfrac{6.5}{0.2}$ **OR** $0.2 = \dfrac{p^2}{6.5}$

$q = 1.74\ (1.74062...)$ ***A1***

$p = 1.14017...\ (1.14)$ ***A1***

[Total 8 marks]