

Markscheme

May 2016

Mathematics

Standard level

Paper 2

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Instructions to Examiners

Abbreviations

- M** Marks awarded for attempting to use a valid **Method**; working must be seen.
- (M)** Marks awarded for a valid **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 SL: Guidance for e-marking May 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, using the RM assessor tool. Please check that you are entering marks for the right question. All the marks will be added and recorded by RM assessor.

If a part is **completely correct**, (and gains all the “must be seen” marks), use the ticks with numbers to stamp full marks. Do **not** use the ticks with numbers for anything else.

- If a part is completely wrong, stamp **A0** by the final answer.
- If a part gains anything else, all the working **must** have annotations stamped to show what marks are awarded. This includes any zero marks.

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. An exception to this rule is when work for **M1** is missing, as opposed to incorrect (see point 4).
- 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 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 **AOA1A1**.
- Where the markscheme specifies (**M2**), **N3**, etc., do **not** split the marks, unless there is a note.
- Most **M** marks are for a **valid** method, ie a method which can lead to the answer: it must indicate some form of progress towards the answer.
- 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 (see examples on next page).

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

If **no** working shown, award **N** marks for **correct** answers – this includes acceptable answers (see accuracy booklet). In this case, ignore mark breakdown (**M**, **A**, **R**). Where a student only shows a final incorrect answer with no working, even if that answer is a correct intermediate answer, award **NO**. *Exceptions to this rule will be noted on the markscheme.*

- 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.
- There may not be a direct relationship between the **N** marks and the implied marks. There are times when all the marks are implied, but the **N** marks are not the full marks: this indicates that we want to see some of the working, without specifying what.
- For consistency within the markscheme, **N** marks are noted for every part, even when these match the mark breakdown.
- If a candidate has incorrect working, which somehow results in a correct answer, do **not** award the **N** marks for this correct answer. However, if the candidate has indicated (usually by crossing out) that the working is to be ignored, award the **N** marks for the correct answer.

4 Implied and must be seen marks

*Implied marks appear in **brackets** eg (M1).*

- Implied marks can only be awarded if the work is seen or if implied in subsequent working (a correct final answer does not necessarily mean that the implied marks are all awarded). There are questions where some working is required, but as it is accepted that not everyone will write the same steps, all the marks are implied, but the **N** marks are not the full marks for the question.
- Normally the correct work is seen in the next line.
- Where there is an (**M1**) followed by **A1** for each correct answer, if no working shown, one correct answer is sufficient evidence to award the (**M1**).

*Must be seen marks appear without **brackets** eg M1.*

- Must be seen marks can only be awarded if the work is seen.
- If a must be seen mark is not awarded because work is missing (as opposed to **M0** or **A0** for incorrect work) all subsequent marks may be awarded if appropriate.

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

*Follow through (FT) marks are awarded where an incorrect answer (final or intermediate) from one **part** of a question is used correctly in **subsequent** part(s) or subpart(s). 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 the only marks awarded in a subpart are for the **final** answer, then **FT** marks should be awarded if appropriate. Examiners are expected to check student work in order to award **FT** marks where appropriate.*

- Within a question part, once an **error** is made, no further **A** marks can be awarded for work which uses the error, but **M** and **R** marks may be awarded if appropriate. (However, as noted above, if an **A** mark is not awarded because work is missing, all subsequent marks may be awarded if appropriate).
- Exceptions to this rule will be explicitly noted on the markscheme.
- 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 probability greater than 1, use of $r > 1$ for the sum of an infinite GP, $\sin \theta = 1.5$, 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 a candidate makes an error in one part, but gets the correct answer(s) to subsequent part(s), award marks as appropriate, unless the question says hence. It is often possible to use a different approach in subsequent parts that does not depend on the answer to previous parts.
- In a “show that” question, if an error in a previous subpart leads to not showing the required answer, do not award the final **A1**. Note that if the error occurs within the same subpart, the **FT** rules may result in further loss of marks.
- Where there are anticipated common errors, the **FT** answers are often noted on the markscheme, to help examiners. It should be stressed that these are not the only **FT** answers accepted, neither should **N** marks be awarded for these answers.

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 is a misread. Do not award the first mark in the question, even if this is an **M** mark, but award all others (if appropriate) so that the candidate only loses one mark for the misread.*

- 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 probability greater than 1, use of $r > 1$ for the sum of an infinite GP, $\sin \theta = 1.5$, 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.

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 parts are indicated by **METHOD 1**, **METHOD 2**, etc.
- Alternative solutions for parts of 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).

10 Calculators

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

Calculator notation The mathematics SL 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.

11 Style

The markscheme aims to present answers using good communication, eg if the question asks to find the value of k , the markscheme will say $k = 3$, but the marks will be for the correct value 3 – there is usually no need for the “ $k =$ ”. In these cases, it is also usually acceptable to have another variable, as long as there is no ambiguity in the question, eg if the question asks to find the value of p and of q , then the student answer needs to be clear. Generally, the only situation where the full answer is required is in a question which asks for equations – in this case the markscheme will say “must be an equation”. Accept sloppy notation in the working, where this is followed by correct working eg $-2^2 = 4$ where they should have written $(-2)^2 = 4$.

*The markscheme often uses words to describe what the marks are for, followed by examples, using the eg notation. These examples are not exhaustive, and examiners should check what candidates have written, to see if they satisfy the description. Where these marks are **M** marks, the examples may include ones using poor notation, to indicate what is acceptable. A valid method is one which will allow candidate to proceed to the next step eg if a quadratic function is given in factorised form, and the question asks for the zeroes, then multiplying the factors does not necessarily help to find the zeros, and would not on its own count as a valid method.*

12 Candidate 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.

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. That is fine, and 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.

13. Diagrams

The notes on how to allocate marks for sketches usually refer to passing through particular points or having certain features. These marks can only be awarded if the sketch is approximately the correct shape. All values given will be an approximate guide to where these points/features occur. In some questions, the first **A1** is for the shape, in others, the marks are only for the points and/or features. In both cases, unless the shape is approximately correct, no marks can be awarded (unless otherwise stated). However, if the graph is based on previous calculations, **FT** marks should be awarded if appropriate.

14. Accuracy of Answers

If the level of accuracy is specified in the question, a mark will be allocated for giving the final 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. Candidates should NO LONGER be penalized for an accuracy error (AP). Examiners should award marks according to the rules given in these instructions and the markscheme. Accuracy is not the same as correctness – an incorrect value does not achieve relevant A marks. It is only final answers which may lose marks for accuracy errors, not intermediate values. Please check work carefully for FT.

Do not accept unfinished numerical final answers such as 3/0.1 (unless otherwise stated). As a rule, numerical answers with more than one part (such as fractions) should be given using integers (eg 6/8). Calculations which lead to integers should be completed, with the exception of fractions which are not whole numbers.

Clarification of intermediate values accuracy instructions

Intermediate values do not need to be given to the correct three significant figures. But, if candidates work with rounded values, this could lead to an incorrect answer, in which case award **A0** for the final answer. However, do not penalise inaccurate intermediate values that lead to an acceptable final answer.

All examiners must read this section carefully

These instructions apply when answers need to be rounded, they do not apply to exact answers which have 3 or fewer figures. The answers will give a range of acceptable values, and any answer given to 3 or more sf that lies in this range will be accepted as well as answers given to the correct 2 sf (which will usually not be in the acceptable range). Answers which are given to 1 sf are not acceptable.

Where numerical answers are required as the **final** answer to a part of a question in the markscheme, the markscheme will show

a truncated 6 sf value (may also have a value based on 3 sf answers)
the exact value if applicable, the correct 3 sf answer and the range of acceptable values. This range includes both end values. Once an acceptable value is seen, ignore any subsequent values (even if rounded incorrectly).
Units (which are generally not required) will appear in brackets at the end.

Example

1.73205

$\sqrt{3}$ (exact), 1.73 [1.73, 1.74] (m)

Note that 1.73 is the correct 3 sf, 1.74 is incorrectly rounded but acceptable, 1.7 is the correct 2 sf value but 1.72 is wrong.

For subsequent parts, the markscheme will show the answers obtained from using unrounded values, and the answers from using previous **correct** 3 sf answers . Examiners will need to check the work carefully if candidates use any other acceptable answers. If other acceptable answers lead to an incorrect final answer (ie outside the range), do not award the final **A1**. This should not be considered as **FT**.

Intermediate values do **not** need to be given to the correct 3 sf. If candidates work with fewer than 3 sf, or with incorrectly rounded values, this could lead to an incorrect answer, in which case award **A0** for the final answer. However, do not penalise intermediate inaccurate values that lead to an acceptable final answer.

In questions where the final answer gains **A2**, if other working shown, award **A1** for an answer with an accuracy error, such as correctly rounded 1 sf answer, or unfinished answer such 4.12π .

If there is **no** working shown, award the **N** marks for **any** acceptable answer, eg in the example above, if 1.73 achieves **N4**, then 1.74, 1.7, 1.7320 all achieve **N4**, but 2 achieves **NO**.

The following table shows what achieves the final mark if this is the **only** numerical answer seen, as long as there is other working.

	Correctly rounded	incorrectly rounded
1sf	No	No
2sf	Yes	No
3sf	Yes	Yes (if in the acceptable range)
4 or more sf	Yes (if in the acceptable range)	Yes (if in the acceptable range)

Examples: The correct marking is given at the end of this section. Please decide what marks you would give each answer, and then check. Assume that working is shown unless otherwise indicated. If you disagree, please discuss with your team leader.

Example 1 (awards **A1** for final answer)

Markscheme		
7.43798		
7.44 [7.43, 7.44]	A1	N3

	Candidate's Script	Marking
(i)	7.43798 followed by anything	
(ii)	7.5	
(iii)	7.4	
(iv)	7.4 (with no working)	
(v)	7	
(vi)	7.438	
(vii)	7.43	
(viii)	7.43 (with no working)	
(ix)	7.437	
(x)	7.433	

Example 2 (awards **A2** for final answer)

Markscheme		
8.43482		
8.43 [8.43, 8.44]	A2	N3

	Candidate's Script	Marking
(i)	8.433016	
(ii)	8.44	
(iii)	8	
(iv)	8.42	
(v)	8.4 (with no working)	
(vi)	8 (with no working)	
(vii)	8.44 (with no working)	
(viii)	8.43 (with no working)	

Answers to the examples.

Example 1 (awards **A1** for final answer)

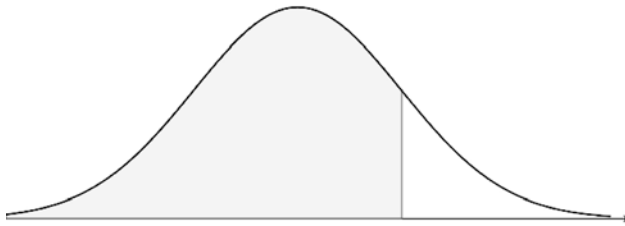
(i)	7.43798 followed by anything	A1
(ii)	7.5 (wrong)	A0
(iii)	7.4 (correct 2 sf)	A1
(iv)	7.4 (with no working)	N3
(v)	7 (1 sf)	A0
(vi)	7.438 (in acceptable range)	A1
(vii)	7.43 (acceptable 3 sf)	A1
(viii)	7.43 (with no working)	N3
(ix)	7.437(in acceptable range)	A1
(x)	7.433(in acceptable range)	A1

Example 2 (awards **A2** for final answer)

	Candidate's Script	Marking
(i)	8.433016 (in acceptable range)	A2
(ii)	8.44	A2
(iii)	8 (1 sf, penalise 1 mark)	A1
(iv)	8.42 (outside acceptable range)	A0
(v)	8.4 (with no working)	N3
(vi)	8 (with no working)	N0
(vii)	8.44 (with no working)	N3
(viii)	8.43 (with no working)	N3

Section A

1. (a)



A1A1 N2

Note: Award **A1** for vertical line clearly to right of mean,
A1 for shading to left of their vertical line.
 Accept shading that continues to the right of the mean if the line does not show.

[2 marks]

(b) $P(X \leq 25) = 0.894350$

(A1)

$P(X \leq 25) = 0.89$ (must be 2 d.p.)

A1 N2
[2 marks]

(c) $c = 22.0976$
 $c = 22.1$ [22.0, 22.1]

A2 N2
[2 marks]

Total [6 marks]

2. (a) valid approach
eg sketch
0, 1.73843

(M1)

$x = 0, x = 1.74$ [1.73, 1.74] (accept (0, 0) and (1.74, 3.02))

A1A1 N3
[3 marks]

(b) integrating and subtracting functions (in any order)
eg $\int g - f$

(M1)

correct substitution of their limits **or** function (accept missing dx)

(A1)

eg $\int_0^{1.74} g - f, \int 3\ln(x+1) - x^2$

Note: Do not award **A1** if there is an error in the substitution.

1.30940

1.31 [1.30, 1.31]

A1 N3
[3 marks]

Total [6 marks]

3. (a) valid approach (M1)
 eg $70 + (180 - 115), 360 - (110 + 115)$
 $\hat{A}BC = 135^\circ$ A1 N2
 [2 marks]
- (b) choosing cosine rule (M1)
 eg $c^2 = a^2 + b^2 - 2ab \cos C$
 correct substitution into RHS (A1)
 eg $5^2 + 8^2 - 2 \times 5 \times 8 \cos 135$
 12.0651
 12.1 [12.0, 12.1] (km) A1 N2
 [3 marks]
- (c) correct substitution (**must** be into sine rule) A1
 eg $\frac{\sin \hat{A}CB}{5} = \frac{\sin 135}{AC}$
 17.0398
 $\hat{A}CB = 17.0$ [17.0, 17.1] (17.0 [16.9, 17.0] from 12.1) A1 N1
 [2 marks]
- Total [7 marks]**

4. (a) valid approach to find the required term (M1)

eg $\binom{9}{r}(x)^{9-r}(2)^r, x^9 + 9x^8(2) + \binom{9}{2}x^7(2)^2 + \dots$, Pascal's triangle to the 9th row

Note: Do not award **M1** for an attempt to multiply $(x+2)(x+2)\dots$, unless further correct working is seen.

identifying correct term (may be indicated in expansion) (A1)

eg 4th term, $r = 6, \binom{9}{3}, (x)^6(2)^3$

correct calculation (may be seen in expansion) (A1)

eg $\binom{9}{3}(x)^6(2)^3, 84 \times 2^3$

$672x^6$ A1 N3

Notes: Do not award any marks if there is clear evidence of adding instead of multiplying. Do not award final **A1** for a final answer of 672, even if $672x^6$ is seen previously. If no working shown, award **N2** for 672.

[4 marks]

(b) valid approach (M1)

eg recognizing x^7 is found when multiplying $5x \times 672x^6$

$3360x^7$ A1 N2

Notes: If working shown, award **M1A0** for 3360, unless they have already lost the final **A1** in part (a) for missing x^6 , in which case award **M1A1**. If no working shown, award **N1** for 3360.

[2 marks]

Total [6 marks]

5.	(a) strong, negative (both required)	A2	N2
		[2 marks]	
	(b) METHOD 1		
	valid approach	(M1)	
	eg $e^{\ln M} = e^{-0.12t+4.67}$		
	correct use of exponent laws for $e^{-0.12t+4.67}$	(A1)	
	eg $e^{-0.12t} \times e^{4.67}$		
	comparing coefficients/terms	(A1)	
	eg $b^t = e^{-0.12t}$		
	$b = e^{-0.12}$ (exact), 0.887 [0.886, 0.887]	A1	N3
	METHOD 2		
	valid approach	(M1)	
	eg $\ln(a \times b^t) = -0.12t + 4.67$		
	correct use of log laws for $\ln(ab^t)$	(A1)	
	eg $\ln a + t \ln b$		
	comparing coefficients	(A1)	
	eg $-0.12 = \ln b$		
	$b = e^{-0.12}$ (exact), 0.887 [0.886, 0.887]	A1	N3
			[4 marks]
			Total [6 marks]

6. correct equation to find r (A1)
 eg $u_1 r^3 = 8u_1, r^3 = 8$
 $r = 2$ (seen anywhere) (A1)
 correct equation to find u_1 A1
 eg $u_1(2^{10} - 1) = 2557.5, u_1 = \frac{2557.5}{r^{10} - 1}(r - 1)$
 $u_1 = 2.5$ (A1)
 $u_{10} = 2.5(2)^9$ (M1)
 1280 A1 N4

Note: Exception to **FT**: if working shown, award full **FT** on an incorrect value of r , or an incorrect method of finding $r = 2$ eg $r = \frac{8}{4}$, which should get **A0A1**, then subsequent marks as per markscheme.

[6 marks]

7. (a) (i) valid approach **(M1)**
 eg $0.9 = e^{k(1)}$
 $k = -0.105360$
 $k = \ln 0.9$ (exact), -0.105 $[-0.106, -0.105]$ **A1 N2**
- (ii) correct interpretation **R1 N1**
 eg population is decreasing, growth rate is negative **[3 marks]**
- (b) **METHOD 1**
- valid approach (accept an equality, but do not accept 0.74) **(M1)**
 eg $P < 0.75P_0$, $P_0e^{kt} < 0.75P_0$, $0.75 = e^{t \ln 0.9}$
- valid approach to solve **their** inequality **(M1)**
 eg logs, graph
- $t > 2.73045$ (accept $t = 2.73045$) (2.73982 from -0.105) **A1**
- 28 years **A2 N2**
- METHOD 2**
- valid approach which gives both crossover values accurate to at least 2 sf **A2**
 eg $\frac{P_{2.7}}{P_0} = 0.75241\dots$, $\frac{P_{2.8}}{P_0} = 0.74452\dots$
- $t = 2.8$ **(A1)**
- 28 years **A2 N2**

Note: If only one “crossover” value and the correct answer are given, award A0(A1)A2 .

[5 marks]

Total [8 marks]

Section B

8. (a) evidence of summing to 1 **(M1)**
 eg $0.55 + 0.3 + 0.1 + k = 1$
 $k = 0.05$ (exact) **A1 N2**
[2 marks]
- (b) (i) 0.55 **A1 N1**
- (ii) recognizing binomial probability **(M1)**
 eg $X \sim B(n, p), \binom{5}{4}, (0.55)^4 (1 - 0.55), \binom{n}{r} p^r q^{n-r}$
 $P(X = 4) = 0.205889$
 $P(X = 4) = 0.206$ [0.205, 0.206] **A1 N2**
[3 marks]
- (c) correct substitution into formula for $E(X)$ **(A1)**
 eg $0.2 + (2 \times 0.08) + (3 \times 0.02)$
 $E(B) = 0.42$ (exact) **A1 N2**
[2 marks]
- (d) (i) valid attempt to find one possible way of having 2 breakdowns **(M1)**
 eg 2A, 2B, 1A and 1B, tree diagram
 one correct calculation for 1 way (seen anywhere) **(A1)**
 eg $0.1 \times 0.7, 0.55 \times 0.08, 0.3 \times 0.2$
 recognizing there are 3 ways of having 2 breakdowns **(M1)**
 eg A twice or B twice or one breakdown each
 correct working **(A1)**
 eg $(0.1 \times 0.7) + (0.55 \times 0.08) + (0.3 \times 0.2)$
 $P(2 \text{ breakdowns}) = 0.174$ (exact) **A1 N3**
- (ii) recognizing conditional probability **(M1)**
 eg $P(A|B), P(2A|2 \text{ breakdowns})$
 correct working **(A1)**
 eg $\frac{0.1 \times 0.7}{0.174}$
 $P(A = 2 | \text{two breakdowns}) = 0.402298$
 $P(A = 2 | \text{two breakdowns}) = 0.402$ [0.402, 0.403] **A1 N2**
[8 marks]

Total [15 marks]

9. (a) **METHOD 1**

recognizing $s = \int v$ (M1)

recognizing displacement of P in first 5 seconds (seen anywhere) (accept missing dt) A1

eg $\int_0^5 v dt, -3.71591$

valid approach to find total displacement (M1)

eg $4 + (-3.7159), s = 4 + \int_0^5 v$

0.284086

0.284 [0.284, 0.285] (m) A2 N3

Note: If no working shown, award **N1** for the answer -3.71591 .

METHOD 2

recognizing $s = \int v$ (M1)

correct integration A1

eg $\frac{1}{3} \sin 3t + 2 \cos t - \frac{t}{2} + c$ (do not penalize missing "c")

attempt to find c (M1)

eg $4 = \frac{1}{3} \sin(0) + 2 \cos(0) - \frac{0}{2} + c, 4 = \frac{1}{3} \sin 3t + 2 \cos t - \frac{t}{2} + c, 2 + c = 4$

attempt to substitute $t = 5$ into their expression with c (M1)

eg $s(5), \frac{1}{3} \sin(15) + 2 \cos(5) - \frac{5}{2} + 2$

0.284086

0.284 [0.284, 0.285] (m) A1 N3
[5 marks]

(b) recognizing that at rest, $v = 0$ (M1)

$t = 0.179900$

$t = 0.180$ [0.179, 0.180] (secs) A1 N2
[2 marks]

(c) recognizing when change of direction occurs (M1)

eg v crosses t axis

2 (times) A1 N2
[2 marks]

continued...

Question 9 continued

(d) acceleration is v' (seen anywhere) (M1)
 eg $v'(3)$
 0.743631
 0.744 [0.743, 0.744] (ms^{-2}) A1 N2
[2 marks]

(e) valid approach involving max or min of v (M1)
 eg $v' = 0, a = 0$, graph
 one correct co-ordinate for min (A1)
 eg 1.14102, -3.27876
 3.28 [3.27, 3.28] (ms^{-1}) A1 N2
[3 marks]

Total [14 marks]

10. (a) valid approach (addition or subtraction) (M1)
 eg $\vec{AO} + \vec{OB}, \vec{B} - \vec{A}$

$$\vec{AB} = \begin{pmatrix} 9 \\ 6 \\ -3 \end{pmatrix}$$
 A1 N2
[2 marks]

(b) **METHOD 1**
 valid approach using $\vec{OC} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$ (M1)

eg $\vec{AC} = \begin{pmatrix} x+3 \\ y+2 \\ z-2 \end{pmatrix}, \vec{CB} = \begin{pmatrix} 6-x \\ 4-y \\ -1-z \end{pmatrix}$

correct working A1

eg $\begin{pmatrix} x+3 \\ y+2 \\ z-2 \end{pmatrix} = \begin{pmatrix} 12-2x \\ 8-2y \\ -2-2z \end{pmatrix}$

all three equations A1

eg $x+3 = 12-2x, y+2 = 8-2y, z-2 = -2-2z,$

$$\vec{OC} = \begin{pmatrix} 3 \\ 2 \\ 0 \end{pmatrix}$$
 AG N0

continued...

Question 10 continued

METHOD 2

valid approach

(M1)

eg $\vec{OC} - \vec{OA} = 2(\vec{OB} - \vec{OC})$

correct working

A1

eg $3\vec{OC} = 2\vec{OB} + \vec{OA}$

correct substitution of \vec{OB} and \vec{OA}

A1

eg $3\vec{OC} = 2\begin{pmatrix} 6 \\ 4 \\ -1 \end{pmatrix} + \begin{pmatrix} -3 \\ -2 \\ 2 \end{pmatrix}, 3\vec{OC} = \begin{pmatrix} 9 \\ 6 \\ 0 \end{pmatrix}$

$\vec{OC} = \begin{pmatrix} 3 \\ 2 \\ 0 \end{pmatrix}$

AG

N0

METHOD 3

valid approach

(M1)

eg $\vec{AC} = \frac{2}{3}\vec{AB}$, diagram, $\vec{CB} = \frac{1}{3}\vec{AB}$



correct working

A1

eg $\vec{AC} = \begin{pmatrix} 6 \\ 4 \\ -2 \end{pmatrix}, \vec{CB} = \begin{pmatrix} 3 \\ 2 \\ -1 \end{pmatrix}$

correct working involving \vec{OC}

A1

eg $\vec{OC} = \begin{pmatrix} -3 \\ -2 \\ 2 \end{pmatrix} + \begin{pmatrix} 6 \\ 4 \\ -2 \end{pmatrix}, \begin{pmatrix} 6 \\ 4 \\ -1 \end{pmatrix} - \begin{pmatrix} 3 \\ 2 \\ -1 \end{pmatrix}$

$\vec{OC} = \begin{pmatrix} 3 \\ 2 \\ 0 \end{pmatrix}$

AG

N0

[3 marks]

continued...

Question 10 continued

(c) finding scalar product and magnitudes (A1)(A1)(A1)
 scalar product = $(9 \times 3) + (6 \times 2) + (-3 \times 0)$ (= 39)

magnitudes $\sqrt{81+36+9}$ (= 11.22), $\sqrt{9+4}$ (= 3.605)

substitution into formula M1

eg $\cos \theta = \frac{(9 \times 3) + 12}{\sqrt{126} \times \sqrt{13}}$

$\theta = 0.270549$ (accept 15.50135°)

$\theta = 0.271$ [0.270, 0.271] (accept 15.5° [15.5, 15.6]) A1 N4
[5 marks]

(d) (i) attempt to use a trig ratio M1

eg $\sin \theta = \frac{DE}{CD}, \left| \vec{CE} \right| = \left| \vec{CD} \right| \cos \theta$

attempt to express \vec{CD} in terms of \vec{OC} M1

eg $\vec{OC} + \vec{CD} = \vec{OD}, OC + CD = OD$

correct working A1

eg $\left| k \vec{OC} - \vec{OC} \right| \sin \theta$

$\left| \vec{DE} \right| = (k - 1) \left| \vec{OC} \right| \sin \theta$ AG N0

(ii) valid approach involving the segment DE (M1)

eg recognizing $\left| \vec{DE} \right| < 3, DE = 3$

correct working (accept equation) (A1)

eg $(k - 1)(\sqrt{13}) \sin 0.271 < 3, k - 1 = 3.11324$

$1 < k < 4.11$ (accept $k < 4.11$ but not $k = 4.11$) A1 N2

[6 marks]

Total [16 marks]