

Markscheme

May 2026

**Mathematics:
applications and interpretation**

Higher level

Paper 1

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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 student 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 students may be advantaged for that specific question item, it is likely that these students 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... (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 students may be using an incorrect value.
- If the student’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 students 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 student 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 student incorrectly copies values or information from the question, this is a mis-read (**MR**). A student 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 students' own work does **not** constitute a misread, it is an error.
- If a student 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

Students 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 student 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 students may also use the correct answer to 3 sf 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: Students 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 student has used any calculator not approved for IB DP examinations (eg CAS enabled devices), please follow the procedures for malpractice.

10 Presentation of student work

Crossed out work: If a student 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 student indicates that they would like the work to be marked.

More than one solution: Where a student offers two or more different answers to the same question, an examiner should only mark the first response unless the student 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) $(a =) 104\,000$

A1

[1 mark]

(b) $105\,144 = 104\,000 \times b^1$

(A1)

$(b =) 1.011$

A1

Note: Answer must be exact; a 3sf answer earns **A0** if the exact answer is not seen.

[2 marks]

(c) $f(10) = 104\,000 \times 1.011^{10}$

(A1)

116023 (116023.2...)

A1

[2 marks]

Note: Answer must be given to the nearest integer for the final **A1** to be awarded.
Award **A0** for an unrealistic **FT** answer that is greater than the Earth's population (8.3 billion or 8.3×10^9).

Total [5 marks]

2. (a) $(20, 30, 240)$

A1A1

[2 marks]

Note: Award **A1** for a coordinate triple that includes at least one correct coordinate. Award **A1A0** for 20, 30, 240 (i.e. no parentheses).

(b) **METHOD 1 – Distance formula in 3D**

recognition that distance between two points in 3D is required

(M1)

$$\sqrt{(20-40)^2 + (30-0)^2 + (240-160)^2}$$

(A1)

$= 87.7 \quad (87.7496..., \sqrt{7700}, 10\sqrt{77}) \text{ cm}$

A1

METHOD 2 – Using Pythagoras theorem twice

$(\text{FB} =) \sqrt{(40-20)^2 + (0-30)^2} (= 36.0555...) \quad \text{AND} \quad (\text{SB} =) 240-160 (= 80)$

(A1)

$(\text{FS} =) \sqrt{36.0555^2 + 80^2}$

(A1)

$(\text{FS} =) 87.7 \quad (87.7496..., \sqrt{7700}, 10\sqrt{77}) \text{ cm}$

A1

[3 marks]

Total [5 marks]

3. (a) $\frac{62}{180} \left(\frac{31}{90}, 0.344444\dots, 34.4\% \right)$ **A1**

[1 mark]

(b) $\frac{19}{53} (0.358490\dots, 35.8\%)$ **A2**

[2 marks]

Note: Award **A1A0** for correct denominator seen if numerator is incorrect.

(c) (H_0 :) age is independent of (preferred type of) drink **A1**

[1 mark]

Note: Do not accept “correlated” or “related”.

(d) GDC work leading to at least one correct answer **(M1)**

(i) ($\chi^2 =$) 3.66 (3.65997...) **A1**

(ii) (p -value =) 0.160 (0.160415...) **A1**

[3 marks]

(e) $3.65997\dots < 9.210$ **OR** $0.160415\dots > 0.01$ **R1**

Note: To award **FT** marks for a comparison using their p -value, p must be between 0 and 1 inclusive.

so, insufficient evidence / fail to reject null hypothesis **A1**

(age is independent of preferred type of drink)

Note: Do not award **R0A1**. Their conclusion must be consistent with their χ^2 or their p -value and their hypothesis.

[2 marks]

Total [9 marks]

4. (i) recognition that a linear model required (M1)
 $c + 3000u = 117.9$ OR $c + 4800u = 179.1$ (A1)
 $u = \$0.034$ A1

- (ii) $c = \$15.90$ A1
 [4 marks]

5. (a) attempt to use the formula for nth term of arithmetic sequence with the given values (M1)
 $(u_{42} =) 18 + (42 - 1)7$
 $= 305$ A1
 [2 marks]

- (b) $9475 = \frac{n}{2}(2 \times 18 + (n - 1) \times 7)$ (A1)
 $3.5n^2 + 14.5n - 9475 = 0$ OR $7n^2 + 29n - 18950 = 0$ A2

Note: Award **A1** for at least one correct term (with the exception of -9475) and equating to 0.

[3 marks]

- (c) an attempt to solve the quadratic equation found in (b). (M1)
 e.g. $(n - 50)(7n + 379)$, sketch
 $(n =) 50$ A1

Note: Award **M1A0** if final answer is "50 or -54.1428..." i.e. both answers given.
 The final **A1ft** is awarded only if n is an integer due to the context.

[2 marks]

Total [7 marks]

6. METHOD 1

attempt to find gradient between any two given points

(M1)

$$(\text{gradient of AB} =) \frac{10-2}{1-5}$$

(A1)

$$= -2$$

$$(\text{equation of AB is}) \quad y-10 = -2(x-1) \quad \text{OR} \quad y-2 = -2(x-5) \quad \text{OR} \quad y = -2x+12$$

A1

EITHER

attempt to find the negative reciprocal of their gradient

(M1)

$$(\text{gradient of CD} =) 0.5$$

$$(\text{equation of CD is}) \quad y-5 = 0.5(x-4) \quad \text{OR} \quad y = 0.5x+3$$

A1

Note: **A1** can be awarded for a correct equation for CD even if **A0** was previously awarded for an incorrect or missing equation of AB.

equating the expressions of their two equations to find intersection point or a sketch of the graph of the simultaneous equations

(M1)

OR

attempt to find an expression for CX where X is any point (x, y) on (AB)

(M1)

$$CX = \sqrt{(4-x)^2 + (5-y)^2} = \sqrt{(4-x)^2 + (-7+2x)^2}$$

A1

attempt to use GDC to find minimum value of CX

(M1)

$$x = 3.6$$

THEN

$$(3.6, 4.8)$$

A1

METHOD 2

$$\text{AB: } \vec{r} = \begin{pmatrix} 1 \\ 10 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ -2 \end{pmatrix} \quad \text{A1A1}$$

EITHER

$$\text{CD: } \vec{r} = \begin{pmatrix} 4 \\ 5 \end{pmatrix} + \mu \begin{pmatrix} 2 \\ 1 \end{pmatrix} \quad \text{A1A1}$$

equate their lines (M1)

$$\lambda = 2.6 \quad \text{(A1)}$$

OR

$$\text{CD}^2 = (\lambda - 3)^2 + (5 - 2\lambda)^2 \quad \text{A1}$$

differentiate and equate to 0 (M1)

$$2(\lambda - 3) - 4(5 - 2\lambda) = 0 \quad \text{(A1)}$$

$$\lambda = 2.6 \quad \text{(A1)}$$

THEN

$$(3.6, 4.8) \quad \text{A1}$$

Note: Accept $x = 3.6$, $y = 4.8$.

Total [7 marks]

7. $y_{n+1} = y_n + 0.1(x_n + \ln(1 + x_n)) \quad \text{(A1)}$

$$x_{n+1} = x_n + 0.1$$

attempt to iterate (M1)

Note: Award **M1** for at least one correct iteration of y seen. e.g. $y(1.1) = 4.16931\dots$

$$(y(1.5) =) 4.99319\dots \quad \text{(A1)}$$

$$4.993 \quad \text{A1}$$

Note: **FT** within the question for the final **A1**, for correctly rounding their $y(1.5)$, seen, to three decimal places.

[4 marks]

8. (a) $N = 60$

$$I\% = 8.4$$

$$PV = (\pm) 30\,000$$

$$FV = 0$$

$$P / Y = 12$$

$$C / Y = 12$$

(M1)(A1)

Note: Award **M1** for attempt to use financial app with at least three entries (not necessarily correct) and **A1** for all entries correct.

$$(PMT =) \$614.05$$

A1

[3 marks]

Note: The final answer must be correct to 2dp to award the final **A1**.
Award **(M1)(A1)A0** if the final answer is -614.05 with or without working.

(b) $N = 24$

$$I\% = 8.4$$

$$PV = (\pm) 30\,000$$

$$PMT = 614.05$$

$$P / Y = 12$$

$$C / Y = 12$$

A1

$$FV = 19\,480.56$$

A1

correct use of financial app with their $(FV - 5000)$ as their PV

(M1)

Note: Award **M1** for their correct PV and FV seen.

$$N = 36$$

$$I\% = 8.4$$

$$PV = (\pm) 14\,480.56$$

$$FV = 0$$

$$P / Y = 12$$

$$C / Y = 12$$

$$(PMT =) \$456.44$$

A1

[4 marks]

Note: Answer must be to 2dp for final **A1** to be awarded, unless already penalized in part (a).

Total [7 marks]

9.

Note: Throughout this question, no follow through if M is not 4 by 4. No follow through in (d).

(a) (i)
$$\begin{pmatrix} 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$
 (M1)A1

Note: Award **M1** for a 4 by 4 matrix seen. Assume row/column headings are A,B,C,D, unless otherwise labelled.

(ii)
$$\begin{pmatrix} 0 & 2 & 0 & 2 \\ 0 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 \\ 0 & 0 & 2 & 0 \end{pmatrix}$$
 A1

[3 marks]

(b) B,D **A1**
[1 mark]

(c) (i)
$$\begin{pmatrix} 0 & 4 & 0 & 4 \\ 0 & 0 & 4 & 0 \\ 4 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 \end{pmatrix}$$
 A1

(ii)
$$\begin{pmatrix} 0 & 8 & 0 & 8 \\ 0 & 0 & 8 & 0 \\ 8 & 0 & 0 & 0 \\ 0 & 0 & 8 & 0 \end{pmatrix}$$
 A1

[2 marks]

(d) 2^{n-1} **A2**
[2 marks]

Total [8 marks]

10. (a) 0.692 (0.692116...)

A2

[2 marks]

Note: Award **A1** for 0.69 .

(b) (i) $H_0 : \rho = 0$

A1

$H_1 : \rho > 0$

A1

Note: If the H_0 and H_1 are omitted (or transposed) award a maximum of **A0A1**.
Accept versions in words, eg no correlation between hours of study and test score for H_0 .

(ii) 0.0286 (0.0285759...)

A2

Note: On follow through from $H_1 : \rho \neq 0, p - \text{value} = 0.057152$.

(iii) since $0.0285759... < 0.05$

R1

Note: Accept correct comparison that uses “ p -value” in place of their 0.0285759..., provided the value was seen in part (b)(ii).

(there is sufficient evidence to) reject H_0

A1

Note: Do not award **R0A1**. Accept a correct conclusion expressed in context.

[6 marks]

Total [8 marks]

11. (a) (7 nodes hence 6 edges required)

AD (4)

A1

Note: Award **A1** for AD as first edge chosen.

CE (5)

DF (7)

A1

Note: Must be in correct order.

BE (9)

AB (9) (BE and AB interchangeable)

A1

(BC (10) rejected)

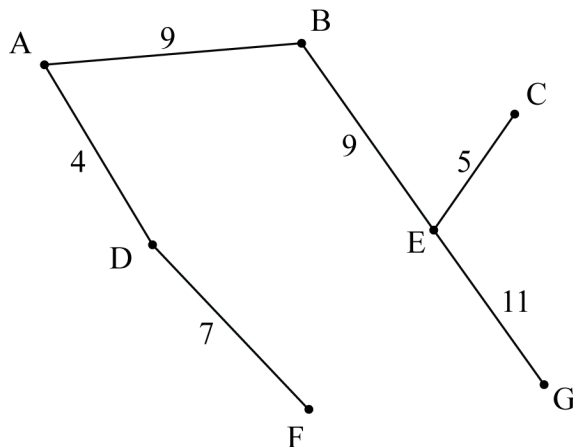
(EF (10) rejected)

EG (11)

A1
[4 marks]

Note: The final **A1** is independent of the preceding **A1** being awarded.
Award a maximum of **A1A1A0A1** for correct MST “by eye”, provided the edges are listed in the correct order (as above); **A0A1A0A1** if the edges are listed in any other order (with no evidence of Kruskal’s).

- (b)



A1
[1 marks]

Note: Only follow through for spanning tree with 6 edges.

- (c) \$45 million

A1
[1 mark]

Total [6 marks]

12. (a) sum of probabilities = 1 (M1)

$$k(16-1^2) + 2k(16-2^2) + 3k(16-3^2) = 1 \quad \text{A1}$$

correct working leading to given result A1

$$\text{e.g. } 15k + 24k + 21k = 1$$

$$k = \frac{1}{60} \quad \text{AG}$$

Note: Award (M1)(A1)A1 if one of $k(16-1^2) + 2k(16-2^2) + 3k(16-3^2) = 1$ or $15k + 24k + 21k = 1$ seen.

[3 marks]

(b) (i) $\frac{24}{60} \left(\frac{2}{5}, 0.4, 40\% \right) \quad \text{A1}$

(ii) attempt to use expected value formula (M1)

$$1 \times \frac{15}{60} + 2 \times \frac{24}{60} + 3 \times \frac{21}{60} = 2.1 \left(\frac{21}{10} \right) \quad \text{A1}$$

[3 marks]

(c) $\left(\frac{15}{60} \right)^2 + \left(\frac{24}{60} \right)^2 + \left(\frac{21}{60} \right)^2 \quad \text{(M1)(M1)}$

Note: Award M1 for one probability squared, M1 for the sum of three probabilities.

$$= \frac{1242}{3600} \left(\frac{69}{200}, 0.345, 34.5\% \right) \quad \text{A1}$$

Note: Award A1 for correct answer in any form, e.g. $\frac{138}{400}$.

[3 marks]

Total [9 marks]

13. (a) recognizing that “at rest” occurs when $v = 0$ (M1)
 $(t =) 3$ seconds A1
 [2 marks]

(b) $s = \int_0^3 |v| dt$ (M1)

Note: For **M1A0** to be awarded, the correct limits must be seen.

1.34 (1.34425...) m A1
 [2 marks]

- (c) attempt to use product rule (M1)
 $a = (6t - 3t^2)e^{-t} - (3t^2 - t^3)e^{-t}$ OR $a = (6t - 6t^2 + t^3)e^{-t}$ A1
 [2 marks]

(d) $t = 0.416$ (0.41577...) seconds A2

Note: Award **A2** for an answer of (0.416, 1.01). Follow through from (c) only for $a = e^{-t} f(t)$ only if $f(t)$ is cubic.

[2 marks]

Total [8 marks]

14. (a) $a - bi$ A1
 [1 mark]

- (b) attempt to expand brackets when multiplying their complex numbers (M1)
 $a^2 + b^2$ A1
 given that $a, b \in \mathbb{R}$, the sum of their squares is also real R1
 therefore zz^* is a real number AG
 [3 marks]

Note: It is possible to award **M1A0R1**, but only if their expression is a real number that does not include i^2 .

(c) $1+2i, 2+i$

A1A1

[2 marks]

Note: Award at most **A1A0** if extra answers are given, e.g. the z^* values.

(d) **EITHER**

$\arctan(2)$ **OR** $\arctan(0.5)$ seen

(M1)

$\arctan(2) + \arctan(0.5)$

OR

$\arg(z_1) + \arg(z_2) = \arg(z_1 z_2)$

(M1)

$= \arg(5i)$

THEN

$= \frac{\pi}{2}$ **OR** 1.57 (1.57079...) **OR** 90

A1

[2 marks]

Total [8 marks]

15. (a) 2

A1

[1 mark]

(b) **EITHER**

graph is not Eulerian

A1

OR

there are vertices with odd degrees / not all vertices are even

A1

[1 mark]

(c) (i) attempt to find minimal pairing of edges

(M1)

QS, UP **OR** QU, SP **OR** QP, SU seen

QS and UP need to be repeated

A2

(ii) (total length=) 197 km

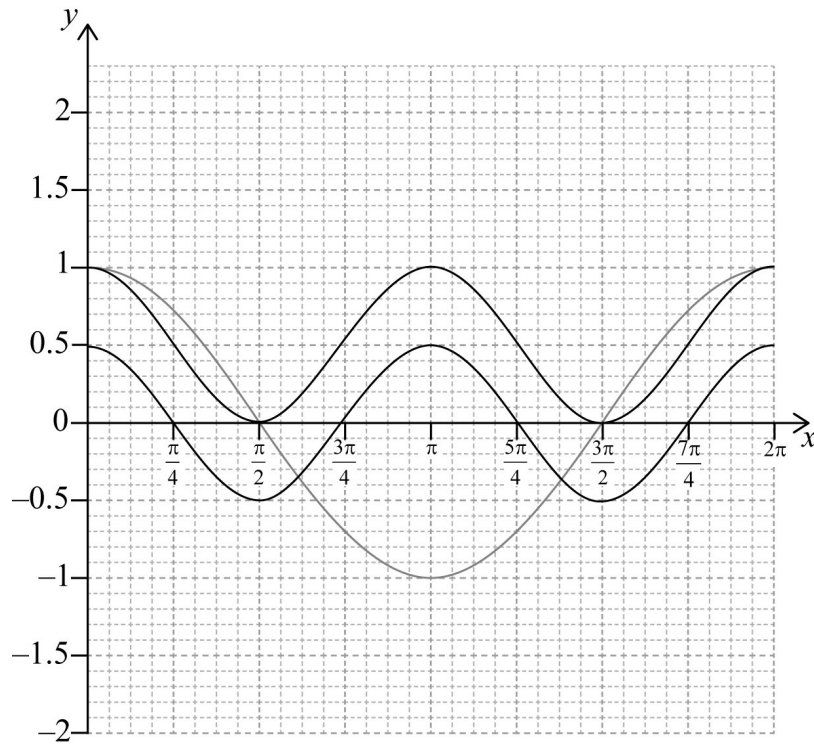
A1

Note: Award **FT** only for two edges to be repeated.

[4 marks]

Total [6 marks]

16. (a)



A1A1

Note: Award **A1** for each correct curve. End points, max and min points must be less than one square from the correct position.

[2 marks]

(b) $h(x) = g(x) + 0.5$

A1

[1 mark]

Note: Only **FT** if their $h(x)$ and $g(x)$ are vertical translations of each other.

(c) (i) $\pi \int_0^{\frac{\pi}{2}} \cos^2(x) dx$ **OR** $\pi \int_0^{\frac{\pi}{2}} (f(x))^2 dx$ **A1A1**

Note: Award **A1** for π and correct integrand, **A1** for correct limits and dx .

(ii) $\pi \int_0^{\frac{\pi}{2}} g(x) + 0.5 dx$ **OR** $\pi \int_0^{\frac{\pi}{2}} 0.5 + 0.5 \cos(2x) dx$ **(M1)**

Note: Award **M1** for writing an integral that uses the result from (b).

$= \pi \left[0.5x + 0.25 \sin(2x) \right]_0^{\frac{\pi}{2}}$ **(M1)A1**

Note: Award **M1** for integrating cosine i.e. $\sin(2x)$ seen, **A1** for a completely correct integrated expression.

substitution of limits leading to $\pi \left[0.5 \frac{\pi}{2} \right]$ **A1**

$= \frac{\pi^2}{4}$ **AG**

[6 marks]

Total [9 marks]
