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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.

- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.

- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.

- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.

- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate’s response is not worthy of credit according to the mark scheme.

- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.

- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
EDEXCEL GCE MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:
   - M marks: method marks are awarded for ‘knowing a method and attempting to apply it’, unless otherwise indicated.
   - A marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
   - B marks are unconditional accuracy marks (independent of M marks)
   - Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol \(\sqrt{}\) will be used for correct ft
- cao – correct answer only
- cso – correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- \* The answer is printed on the paper
- [ ] The second mark is dependent on gaining the first mark
- dM1 denotes a method mark which is dependent upon the award of the previous method mark.

4. All A marks are ‘correct answer only’ (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.
6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.
General Principles for Core Mathematics Marking
(But note that specific mark schemes may sometimes override these general principles).

Method mark for solving 3 term quadratic:

1. Factorisation

\[(x^2 + bx + c) = (x + p)(x + q), \text{ where } |pq| = |c|, \text{ leading to } x = \ldots\]

\[(ax^2 + bx + c) = (mx + p)(nx + q), \text{ where } |pq| = |c| \text{ and } |mn| = |a|, \text{ leading to } x = \ldots\]

2. Formula

Attempt to use the correct formula (with values for a, b and c).

3. Completing the square

Solving \(x^2 + bx + c = 0\):
\[
\left( x \pm \frac{b}{2} \right)^2 \pm q \pm c = 0, \quad q \neq 0, \text{ leading to } x = \ldots
\]

Method marks for differentiation and integration:

1. Differentiation

Power of at least one term decreased by 1. \((x^n \to x^{n-1})\)

2. Integration

Power of at least one term increased by 1. \((x^n \to x^{n+1})\)
**Use of a formula**

Where a method involves using a formula that has been learnt, the advice given in recent examiners’ reports is that the formula should be quoted first.

Normal marking procedure is as follows:

**Method mark** for quoting a correct formula and attempting to use it, even if there are small errors in the substitution of values.

Where the formula is **not** quoted, the method mark can be gained by implication from **correct** working with values, but may be lost if there is any mistake in the working.

**Exact answers**

Examiners’ reports have emphasised that where, for example, an exact answer is asked for, or working with surds is clearly required, marks will normally be lost if the candidate resorts to using rounded decimals.
1. \(x^3 + 2xy - x - y^3 - 20 = 0\)

(a) \[
\begin{align*}
\left\{ \frac{\partial}{\partial x} \right\} 3x^2 + \left(2y + 2x \frac{dy}{dx}\right) - 1 - 3y^2 \frac{dy}{dx} &= 0 \\
3x^2 + 2y - 1 + \left(2x - 3y^2\right) \frac{dy}{dx} &= 0 \\
\frac{dy}{dx} &= \frac{3x^2 + 2y - 1}{3y^2 - 2x} \quad \text{or} \quad -1 - 3x^2 - 2y = 2x - 3y^2.
\end{align*}
\]

M1 A1 B1

(b) At \(P(3, -2)\), \(m(T) = \frac{dy}{dx} = \frac{3(3)^2 + 2(-2) - 1}{3(-2)^2 - 2(3)} = \frac{22}{6}\) or \(\frac{11}{3}\).

and either \(T: y - 2 = \frac{11}{3} (x - 3)\), \(y = \frac{11}{3} (x - 3) + c \Rightarrow c = \ldots\).

or \((-2) = \left(\frac{11}{3}\right) (3) + c \Rightarrow c = \ldots\).

\(T: 11x - 3y - 39 = 0\) or \(K(11x - 3y - 39) = 0\)

A1 cso

Alternative method for part (a)

(a) \[
\begin{align*}
\left\{ \frac{\partial}{\partial x} \right\} 3x^2 + \left(2y + 2x \frac{dy}{dx}\right) - \frac{dx}{dy} - 3y^2 &= 0 \\
2x - 3y^2 + \left(3x^2 + 2y - 1\right) \frac{dx}{dy} &= 0 \\
\frac{dy}{dx} &= \frac{3x^2 + 2y - 1}{3y^2 - 2x} \quad \text{or} \quad -1 - 3x^2 - 2y = 2x - 3y^2.
\end{align*}
\]

M1 A1 B1

Question 1 Notes

(a) General Note

Writing down \(\frac{dy}{dx} = \frac{3x^2 + 2y - 1}{3y^2 - 2x}\) or \(-1 - 3x^2 - 2y = 2x - 3y^2\) from no working is full marks.

Note Writing down \(\frac{dy}{dx} = \frac{3x^2 + 2y - 1}{2x - 3y^2}\) or \(-1 - 3x^2 - 2y = \frac{3y^2 - 2x}{2x - 3y^2}\) from no working is M1A0B0M1A0

Note Few candidates will write \(3x^2 + 2y + 2x \frac{dy}{dx} - 1 - 3y^2 \frac{dy}{dx} = 0\) leading to \(\frac{dy}{dx} = \frac{3x^2 + 2y - 1}{3y^2 - 2x}\), o.e.

This should get full marks.

1. (a) M1 Differentiates implicitly to include either \(2x \frac{dy}{dx}\) or \(-y^3 \rightarrow k y \frac{dy}{dx}\). (Ignore \(\frac{dy}{dx} = \).)

A1 \(x^3 \rightarrow 3x^2\) and \(-x - y^3 - 20 = 0 \rightarrow -1 - 3y^2 \frac{dy}{dx} = 0\)

B1 \(2xy \rightarrow 2y + 2x \frac{dy}{dx}\)

Note If an extra term appears then award 1st A0.
1. (a)  

**Note**  
3x^2 + 2y + 2x \frac{dy}{dx} - 1 - 3y^2 \frac{dy}{dx} \rightarrow 3x^2 + 2y - 1 = 3y^2 \frac{dy}{dx} - 2x \frac{dy}{dx}

will get 1st A1 (implied) as the " = 0" can be implied by rearrangement of their equation.

**dM1 dependent on the first method mark being awarded.**  
An attempt to factorise out all the terms in \( \frac{dy}{dx} \) as long as there are at least two terms in \( \frac{dy}{dx} \).  

\[ ... + (2x - 3y^2) \frac{dy}{dx} = ... \]

**Note**  
Placing an extra \( \frac{dy}{dx} \) at the beginning and then including it in their factorisation is fine for dM1.

**A1**  
For \( \frac{1 - 2y - 3x^2}{2x - 3y^2} \) or equivalent. Eg: \( 3x^2 + 2y - 1 \)

\( \frac{3y^2}{2x - 3y^2} \)

cso: If the candidate’s solution is not completely correct, then do not give this mark.

**isw**  
You can, however, ignore subsequent working following on from correct solution.

---

1. (b)  

**M1 Some** attempt to substitute both \( x = 3 \) and \( y = -2 \) into their \( \frac{dy}{dx} \) which contains both \( x \) and \( y \) to find \( m_r \) and

- either applies \( y - 2 = (\text{their } m_r)(x - 3) \), where \( m_r \) is a numerical value.
- or finds \( c \) by solving \( (-2) = (\text{their } m_r)(3) + c \), where \( m_r \) is a numerical value.

**Note**  
Using a changed gradient (i.e. applying \( -1 \) \( \frac{dx}{dy} \) or \( \frac{1}{\frac{dx}{dy}} \) is M0).

**A1**  
Accept any integer multiple of \( 11x - 3y - 39 = 0 \) or \( 11x - 39 - 3y = 0 \) or \( -11x + 3y + 39 = 0 \), where their tangent equation is equal to 0.

cso: A correct solution is required from a correct \( \frac{dy}{dx} \).

**isw**  
You can ignore subsequent working following a correct solution.

---

**Alternative method for part (a): Differentiating with respect to \( y \)**

1. (a)  

**M1**  
Differentiates implicitly to include either \( 2y \frac{dx}{dy} \) or \( x^3 \rightarrow \pm kx^2 \frac{dx}{dy} \) or \( -x \rightarrow -\frac{dx}{dy} \)

\( \text{(Ignore } \frac{dx}{dy} = 0 \text{).} \)

**A1**  
\( x^3 \rightarrow 3x^2 \frac{dy}{dx} \) and \( -x - y^3 - 20 = 0 \rightarrow -\frac{dy}{dx} - 3y^2 = 0 \)

**B1**  
\( 2xy \rightarrow 2y \frac{dx}{dy} + 2x \)

**dM1 dependent on the first method mark being awarded.**  
An attempt to factorise out all the terms in \( \frac{dx}{dy} \) as long as there are at least two terms in \( \frac{dx}{dy} \).  

**A1**  
For \( \frac{1 - 2y - 3x^2}{2x - 3y^2} \) or equivalent. Eg: \( \frac{3x^2 + 2y - 1}{3y^2 - 2x} \)

cso: If the candidate’s solution is not completely correct, then do not give this mark.
**Question Number** | **Scheme** | **Marks**
--- | --- | ---
2. | \[
(1 + kx)^{-4} = 1 + (-4)(kx) + \frac{(-4)(-4-1)}{2!}(kx)^2 + ...
\] | M1
(a) | Either \((-4)k = -6\) or \((1 + kx)^{-4} = 1 + (-4)(kx)\) see notes leading to \(k = \frac{3}{2}\) or \(1.5\) or \(\frac{6}{4}\) | A1
(b) | \[
\frac{(-4)(-5)}{2!}k^2
\] | M1
\[
\left\{ A = \frac{(-4)(-5)}{2!} \left(\frac{3}{2}\right)^2 \right\} \Rightarrow A = \frac{45}{2}
\] | M1
| \[
\frac{45}{2} \text{ or } 22.5
\] | A1

**Question 2 Notes**

**Note** In this question ignore part labelling and mark part (a) and part (b) together.

**Note** Writing down \(\{(1 + kx)^{-4}\} = 1 + (-4)(kx) + \frac{(-4)(-4-1)}{2!}(kx)^2 + ...
\) gets all the method marks in Q2. i.e. (a) M1 and (b) M1M1

(a) **M1** Award M1 for
- either writing down \((-4)k = -6\) or \(4k = 6\)
- or expanding \((1 + kx)^{-4}\) to give \(1 + (-4)(kx)\)
- or writing down \((-4)kx = -6\) or \((-4k) = -6x\) or \(-4kx = -6x\)

**A1** \(k = \frac{3}{2}\) or \(1.5\) or \(\frac{6}{4}\) from no incorrect sign errors.

**Note** The M1 mark can be implied by a candidate writing down the correct value of \(k\).

**Note** Award M1 for writing down \(4k = 6\) and then A1 for \(k = 1.5\) (or equivalent).

**Note** Award M0 for \(4k = -6\) (if there is no evidence that \((1 + kx)^{-4}\) expands to give \(1 + (-4)(kx) + ...\))

**Note** \(1 + (-4)(kx)\) leading to \((-4)k = 6\) leading to \(k = \frac{3}{2}\) is M1A0.

(b) **M1** For either \(\frac{(-4)(-4-1)}{2!}k\) or \(\frac{(-4)(-5)}{2!}k^2\) or \(10\) or \((k)^2\) or \((kx)^2\)

**M1** Either \(\frac{(-4)(-4-1)}{2!}k^2\) or \(\frac{(-4)(-5)}{2!}k^2\) or \(\frac{(-4)(-5)}{2!}k^2\) or \(\frac{(-4)(-5)}{2!}k^2\) (their \(k\)) or \(10k^2\)

**Note** Candidates are allowed to use 2 instead of 2!

**A1** Uses \(k = 1.5\) to give \(A = \frac{45}{2}\) or 22.5

Note \(A = \frac{90}{4}\) which has not been simplified is A0.

**Note** Award A0 for \(A = \frac{45}{2}x^2\).

**Note** Allow A1 for \(A = \frac{45}{2}x^2\) followed by \(A = \frac{45}{2}\)

**Note** \(k = -1.5\) leading to \(A = \frac{45}{2}\) or 22.5 is A0.
Question 3 Notes

3. (a) B1 0.68212 correct answer only. Look for this on the table or in the candidate’s working.

(b) B1 Outside brackets $\frac{1}{2} \times 1$ or $\frac{1}{2}$ or equivalent.

M1 For structure of trapezium rule $\text{[ ........... ]}$

Note No errors are allowed [eg. an omission of a y-ordinate or an extra y-ordinate or a repeated y ordinate].

A1 anything that rounds to 2.5774

Note Working must be seen to demonstrate the use of the trapezium rule. (Actual area is 2.51314428…)

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Scheme</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>y</td>
<td>1.42857</td>
<td>0.90326</td>
</tr>
<tr>
<td>(a)</td>
<td>{At x = 3,} $y = 0.68212$ (5 dp) [0.68212]</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>$\frac{1}{2} \times 1 \times \left[1.42857 + 0.55556 + 2\left(0.90326 + \text{their} \ 0.68212\right)\right]$ [Outside brackets $\frac{1}{2} \times 1$ or $\frac{1}{2}$] For structure of $\text{[ ........... ]}$ [B1 aef]</td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td>[= \frac{1}{2}(5.15489)] $= 2.577445 = 2.5774$ (4 dp) [anything that rounds to 2.5774] [A1]</td>
<td></td>
</tr>
<tr>
<td>(d)</td>
<td>(u = \sqrt{x} \Rightarrow \frac{du}{dx} = \frac{1}{2}x^{-\frac{1}{2}}) or $\frac{dx}{du} = 2u$ [B1]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\int \frac{10}{2u^2 + 5u} \cdot 2u \ du) [Either (\int \pm ku\ \alpha u^2 \pm \beta u \ {du}) or (\int \pm k\ \frac{\alpha u^2 \pm \beta u}{u} \ {du}) [M1]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\left{\int \frac{20}{2u + 5} \ du\right} = \frac{20}{2} \ln(2u + 5)) [± \lambda \ln(2u + 5)] or $\pm \lambda \ln\left(u + \frac{5}{2}\right)$, $\lambda \neq 0$ [M1]</td>
<td></td>
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<tr>
<td></td>
<td>$\frac{20}{2u + 5} \rightarrow \frac{20}{2} \ln(2u + 5)) or $10\ln\left(u + \frac{5}{2}\right)$ [A1 cso]</td>
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</tr>
<tr>
<td></td>
<td>(\left[\frac{20}{2} \ln(2u + 5)\right]^2\text{,}_1} = 10\ln(2(2) + 5) - 10\ln(2(1) + 5)) [M1]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(10\ln 9 - 10\ln 7) or $10\ln\left(\frac{9}{7}\right)$ or (20\ln 3 - 10\ln 7) [A1 oe cso]</td>
<td></td>
</tr>
</tbody>
</table>
3. (b) contd

**Bracketing mistake:** Unless the final answer implies that the calculation has been done correctly
award B1M0A0 for \( \frac{1}{2} \times 1 + 1.42857 + 2(0.90326 + \text{their } 0.68212) + 0.55556 \) (nb: answer of 5.65489).
award B1M0A0 for \( \frac{1}{2} \times 1 \) (1.42857 + 0.55556) + 2(0.90326 + their 0.68212) (nb: answer of 4.162825).

**Alternative method:** Adding individual trapezia

\[
\text{Area} \approx 1 \times \left[ \frac{1.42857 + 0.90326 + 0.68212 + 0.55556}{2} \right] = 2.577445
\]

**Note**
- B1: 1 and a divisor of 2 on all terms inside brackets.
- M1: First and last ordinates once and two of the middle ordinates twice inside brackets ignoring the 2.
- A1: anything that rounds to 2.5774

(c) **B1** Overestimate and either trapezia lie above curve **or** a diagram that gives reference to the extra area

eg. This diagram is sufficient. It must show the top of a trapezium lying above the curve.

**Note** Reason of “gradient is negative” by itself is B0.

(d) **B1**
\[
\frac{d}{dx} = \frac{1}{2} \sqrt{x}^{-\frac{1}{2}} \quad \text{or} \quad \frac{d}{dx} = \frac{1}{2 \sqrt{x}}
\]

**M1** Applying the substitution and achieving \( \int \pm \frac{k}{u} \pm \beta \left\{ \frac{du}{u^\pm \beta} \right\} \), \( k, \alpha, \beta \neq 0 \). Integral sign and \( du \) not required for this mark.

**M1** Cancelling \( u \) and integrates to achieve \( \pm \lambda \ln(2u + 5) \) or \( \pm \lambda \ln \left( u + \frac{5}{2} \right) \), \( \lambda \neq 0 \) with no other terms.

**A1** cso. Integrates \( \frac{20}{2u + 5} \) to give \( \frac{20}{2} \ln(2u + 5) \) or \( 10 \ln \left( u + \frac{5}{2} \right) \), un-simplified or simplified.

**Note** BE CAREFUL! Candidates must be integrating \( \frac{20}{2u + 5} \) or equivalent.

So \( \int \frac{10}{2u + 5} \, du = 10 \ln(2u + 5) \) WOULD BE A0 and final A0.

**M1** Applies limits of 2 and 1 in \( u \) or 4 and 1 in \( x \) in their (i.e. any) changed function and subtracts the correct way round.

**A1** Exact answers of either \( 10 \ln 9 - 10 \ln 7 \) or \( 10 \ln \left( \frac{9}{7} \right) \) or \( 20 \ln 3 - 10 \ln 7 \) or \( 20 \ln \left( \frac{3}{\sqrt{7}} \right) \) or \( \ln \left( \frac{9^u}{7^u} \right) \)
or equivalent. **Correct solution only.**

**Note** You can ignore subsequent working which follows from a correct answer.

**Note** A decimal answer of 2.513144283... (without a correct exact answer) is A0.
<table>
<thead>
<tr>
<th>Question Number</th>
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<th>Marks</th>
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<tbody>
<tr>
<td>4.</td>
<td>$\frac{dV}{dt} = 80\pi, \ V = 4\pi h(h + 4) = 4\pi h^2 + 16\pi h,$ $\frac{dV}{dh} = 8\pi h + 16\pi$ $\pm \alpha h \pm \beta$, $\alpha \neq 0$, $\beta \neq 0$</td>
<td>$\pm \alpha h \pm \beta$, $\alpha \neq 0$, $\beta \neq 0$ $8\pi h + 16\pi$</td>
</tr>
<tr>
<td></td>
<td>$\left(\frac{dV}{dh}\right) \frac{dh}{dt} = \frac{dV}{dt} \Rightarrow \left(8\pi h + 16\pi\right) \frac{dh}{dt} = 80\pi$</td>
<td>$M1$ $A1$</td>
</tr>
<tr>
<td></td>
<td>$\left{ \frac{dh}{dt} = \frac{dV}{dh} \Rightarrow \frac{dh}{dt} = 80\pi \times \frac{1}{8\pi h + 16\pi} \right}$</td>
<td>$80\pi \div \text{Candidate's} \ \frac{dV}{dh}$</td>
</tr>
<tr>
<td></td>
<td>When $h = 6$, $\left{ \frac{dh}{dt} = \frac{1}{8\pi(6) + 16\pi} \times 80\pi \right}$ dependent on the previous M1 mark</td>
<td>$dM1$</td>
</tr>
<tr>
<td></td>
<td>$\frac{dh}{dt} = 1.25 \ (\text{cm}^2)\text{s}^{-1}$</td>
<td>$1.25 \text{ or } \frac{5}{4} \text{ or } \frac{10}{8} \text{ or } \frac{80}{64}$</td>
</tr>
</tbody>
</table>

### Alternative Method for the first M1A1

**Product rule:**

$\left\{ \begin{array}{l} u = 4\pi h \\
v = h + 4 \end{array} \right\}
\begin{array}{l}
\frac{du}{dh} = 4\pi \\
\frac{dv}{dh} = 1
\end{array}
\Rightarrow
\frac{dV}{dh} = 4\pi(h + 4) + 4\pi h$ $\pm \alpha h \pm \beta$, $\alpha \neq 0$, $\beta \neq 0$ $4\pi(h + 4) + 4\pi h$ $M1$ $A1$

### Question 4 Notes

**M1** An expression of the form $\pm \alpha h \pm \beta$, $\alpha \neq 0$, $\beta \neq 0$. Can be simplified or un-simplified.

**A1** Correct simplified or un-simplified differentiation of $V$.

**Note** Some candidates will use the product rule to differentiate $V$ with respect to $h$. (See Alt Method 1).

**Note** $\frac{dV}{dh}$ does not have to be explicitly stated, but it should be clear that they are differentiating their $V$.

**M1** $(\text{Candidate's} \ \frac{dV}{dh}) \times \frac{dh}{dt} = 80\pi$ or $80\pi \div \text{Candidate's} \ \frac{dV}{dh}$

**Note** Also allow 2$^{nd}$ M1 for $(\text{Candidate's} \ \frac{dV}{dh}) \times \frac{dh}{dr} = 80\pi$ or $80\pi \div \text{Candidate's} \ \frac{dV}{dh}$

**Note** Give 2$^{nd}$ M0 for $(\text{Candidate's} \ \frac{dV}{dh}) \times \frac{dh}{dr} = 80\pi t$ or $80k$ or $80\pi t$ or $80k \div \text{Candidate's} \ \frac{dV}{dh}$

**dM1** which is dependent on the previous M1 mark.

Substitutes $h = 6$ into an expression which is a result of a quotient of their $\frac{dV}{dh}$ and $80\pi$ (or 80)

**A1** $1.25 \text{ or } \frac{5}{4} \text{ or } \frac{10}{8} \text{ or } \frac{80}{64}$ (units are not required).

**Note** $80\pi$ $64\pi$ as a final answer is A0.

**Note** Substituting $h = 6$ into a correct $\frac{dV}{dh}$ gives $64\pi$ but the final M1 mark can only be awarded if this is used as a quotient with $80\pi$ (or 80).
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>5.</td>
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<tr>
<td></td>
<td>( x = 4\cos\left(t + \frac{\pi}{6}\right), \quad y = 2\sin t )</td>
<td></td>
</tr>
<tr>
<td><strong>Main Scheme</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>( x = 4\cos\left(t + \frac{\pi}{6}\right) - \sin t\sin\left(\frac{\pi}{6}\right) )</td>
<td>( \cos\left(t + \frac{\pi}{6}\right) \rightarrow \cos t\cos\left(\frac{\pi}{6}\right) \pm \sin t\sin\left(\frac{\pi}{6}\right) ) M1 oe</td>
</tr>
<tr>
<td></td>
<td>( x = 4\cos\left(t + \frac{\pi}{6}\right) - \sin t\sin\left(\frac{\pi}{6}\right) )</td>
<td>Add their expanded ( x ) (which is in terms of ( t )) to ( 2\sin t ) dM1</td>
</tr>
<tr>
<td></td>
<td>( = 4\left(\frac{\sqrt{3}}{2}\cos t - \frac{1}{2}\sin t\right) + 2\sin t )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( = 2\sqrt{3}\cos t ) *</td>
<td>Correct proof A1 *</td>
</tr>
<tr>
<td>(a)</td>
<td><strong>Alternative Method 1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( x = 4\cos\left(t + \frac{\pi}{6}\right) - \sin t\sin\left(\frac{\pi}{6}\right) )</td>
<td>( \cos\left(t + \frac{\pi}{6}\right) \rightarrow \cos t\cos\left(\frac{\pi}{6}\right) \pm \sin t\sin\left(\frac{\pi}{6}\right) ) M1 oe</td>
</tr>
<tr>
<td></td>
<td>( = 4\left(\frac{\sqrt{3}}{2}\cos t - \frac{1}{2}\sin t\right) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( = 2\sqrt{3}\cos t - 2\sin t )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>So, ( x = 2\sqrt{3}\cos t - y )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( x + y = 2\sqrt{3}\cos t ) *</td>
<td>Forms an equation in ( x, y ) and ( t ). dM1</td>
</tr>
<tr>
<td></td>
<td>So, ( x + y = 2\sqrt{3}\cos t ) *</td>
<td>Correct proof A1 *</td>
</tr>
<tr>
<td>(b)</td>
<td><strong>Main Scheme</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \left(\frac{x + y}{2\sqrt{3}}\right)^2 + \left(\frac{y}{2}\right)^2 = 1 )</td>
<td></td>
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<tr>
<td></td>
<td>( \Rightarrow \left(x + y\right)^2 + \frac{y^2}{4} = 1 )</td>
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<tr>
<td></td>
<td>( \Rightarrow \left(x + y\right)^2 + 3y^2 = 12 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \left{a = 3, \ b = 12\right} )</td>
<td>A1</td>
</tr>
<tr>
<td>(b)</td>
<td><strong>Alternative Method 1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (x + y)^2 = 12\cos^2 t = 12(1 - \sin^2 t) = 12 - 12\sin^2 t )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \Rightarrow (x + y)^2 = 12 - 3y^2 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \Rightarrow (x + y)^2 + 3y^2 = 12 )</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td><strong>Alternative Method 2</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( (x + y)^2 = 12\cos^2 t )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>As ( 12\cos^2 t + 12\sin^2 t = 12 )</td>
<td></td>
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<tr>
<td></td>
<td>then ( (x + y)^2 + 3y^2 = 12 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \left{a = 3, \ b = 12\right} )</td>
<td>A1</td>
</tr>
</tbody>
</table>

\[5\]
<table>
<thead>
<tr>
<th>Question 5 Notes</th>
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</thead>
<tbody>
<tr>
<td><strong>5. (a)</strong> M1</td>
</tr>
<tr>
<td><strong>Note</strong> If a candidate states ( \cos(A + B) = \cos A \cos B \pm \sin A \sin B ), but there is an error <em>in its application</em> then give M1.</td>
</tr>
<tr>
<td><strong>Main</strong> dM1</td>
</tr>
<tr>
<td><strong>Note</strong> Adds their expanded ( x ) (which is in terms of ( t )) to ( 2 \sin t )</td>
</tr>
<tr>
<td>Writing ( x + y = ... ) is not needed in the <strong>Main Scheme</strong> method.</td>
</tr>
<tr>
<td><strong>Alt 1</strong> dM1</td>
</tr>
<tr>
<td>Forms an equation in ( x, y ) and ( t ).</td>
</tr>
<tr>
<td><strong>A1</strong> Evidence of ( \cos \left( \frac{\pi}{6} \right) ) and ( \sin \left( \frac{\pi}{6} \right) ) evaluated and the proof is correct with no errors.</td>
</tr>
<tr>
<td><strong>Note</strong> ( {x + y} = 4 \cos \left( t + \frac{\pi}{6} \right) + 2 \sin t ), by itself is M0M0A0.</td>
</tr>
<tr>
<td><strong>(b)</strong> M1</td>
</tr>
<tr>
<td>Applies ( \cos^2 t + \sin^2 t = 1 ) to achieve an equation containing <em>only</em> ( x )'s and ( y )'s.</td>
</tr>
<tr>
<td><strong>A1</strong> leading ((x + y)^2 + 3y^2 = 12)</td>
</tr>
<tr>
<td><strong>SC</strong> Award <strong>Special Case B1B0</strong> for a candidate who writes down either</td>
</tr>
<tr>
<td>* ((x + y)^2 + 3y^2 = 12) from no working</td>
</tr>
<tr>
<td>* (a = 3, b = 12), but does not provide a correct proof.</td>
</tr>
<tr>
<td><strong>Note</strong> Alternative method 2 is fine for M1 A1</td>
</tr>
<tr>
<td><strong>Note</strong> Writing ((x + y)^2 = 12 \cos^2 t) followed by (12 \cos^2 t + a(4 \sin^2 t) = b \Rightarrow a = 3, b = 12) is SC: B1B0</td>
</tr>
<tr>
<td><strong>Note</strong> Writing ((x + y)^2 = 12 \cos^2 t) followed by (12 \cos^2 t + a(4 \sin^2 t) = b)</td>
</tr>
<tr>
<td>* states (a = 3, b = 12)</td>
</tr>
<tr>
<td>* and refers to either ( \cos^2 t + \sin^2 t = 1 ) or (12 \cos^2 t + 12 \sin^2 t = 12)</td>
</tr>
<tr>
<td>* and there is no incorrect working () would get M1A1</td>
</tr>
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</table>
### Question 6

#### (i)
\[
\int xe^{4x} \, dx = \frac{1}{4}xe^{4x} - \int \frac{1}{4}e^{4x} \, \{dx\}
\]
\[
= \frac{1}{4}xe^{4x} - \frac{1}{16}e^{4x} + c
\]
\[
\pm \alpha xe^{4x} - \beta e^{4x} \, \{dx\}, \quad \alpha \neq 0, \beta > 0
\]

#### (ii)
\[
\int \frac{8}{(2x-1)^3} \, dx = \frac{8(2x-1)^2}{(2)(-2)} + c
\]
\[
\{= \frac{1}{2(2x-1)^2} + c\}
\]
\[
\pm \lambda (2x-1)^2
\]

#### (iii)
\[
\frac{dy}{dx} = e^x \csc 2y \csc y \quad y = \frac{\pi}{6} \text{ at } x = 0
\]

<table>
<thead>
<tr>
<th>Main Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ \int \frac{1}{\csc 2y \csc y} , dy = \int e^x , dx \quad \text{or} \quad \int \sin 2y \sin y , dy = \int e^x , dx ]</td>
</tr>
<tr>
<td>Applying ( \frac{1}{\csc 2y} ) or ( \sin 2y \rightarrow 2\sin y \cos y )</td>
</tr>
<tr>
<td>Integrates to give ( \pm \mu \sin^3 y )</td>
</tr>
<tr>
<td>( 2\sin^2 y \cos y \rightarrow \frac{2}{3}\sin^3 y )</td>
</tr>
<tr>
<td>( e^x \rightarrow e^x )</td>
</tr>
<tr>
<td>( \Rightarrow c = -\frac{11}{12} ) giving ( \frac{2}{3}\sin^3 y = e^x - \frac{11}{12} )</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternative Method 1</th>
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</thead>
<tbody>
<tr>
<td>[ \int \frac{1}{\csc 2y \csc y} , dy = \int e^x , dx \quad \text{or} \quad \int \sin 2y \sin y , dy = \int e^x , dx ]</td>
</tr>
<tr>
<td>Integrates to give ( \pm \alpha \sin 3y \pm \beta \sin y )</td>
</tr>
<tr>
<td>( \frac{1}{2}(\cos 3y - \cos y) )</td>
</tr>
<tr>
<td>( -\frac{1}{2}(\frac{1}{3}\sin 3y - \sin y) = e^x {+ c} )</td>
</tr>
<tr>
<td>( e^x \rightarrow e^x \text{ as part of solving their DE.} )</td>
</tr>
<tr>
<td>Use of ( y = \frac{\pi}{6} ) and ( x = 0 ) in an integrated equation containing ( c )</td>
</tr>
<tr>
<td>( \Rightarrow c = -\frac{11}{12} ) giving ( -\frac{1}{6}\sin 3y + \frac{1}{2}\sin y = e^x - \frac{11}{12} )</td>
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<thead>
<tr>
<th>Marks</th>
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<tbody>
<tr>
<td>M1</td>
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<td>A1</td>
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<tr>
<td>[3]</td>
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<tr>
<td>M1</td>
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<tr>
<td>A1</td>
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<tr>
<td>[2]</td>
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<tr>
<td>B1 oe</td>
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<tr>
<td>M1</td>
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<td>A1</td>
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<td>[7]</td>
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<td>B1 oe</td>
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<td>A1</td>
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<td>B1</td>
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<tr>
<td>M1</td>
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<tr>
<td>A1</td>
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<tr>
<td>[7]</td>
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</table>
Question 6 Notes

6. (i) M1 Integration by parts is applied in the form \( \pm \alpha xe^{\beta x} - \int \beta e^{\beta x} \{dx\} \), where \( \alpha \neq 0, \beta > 0 \). (must be in this form).
A1 \( \frac{1}{4} xe^{\beta x} - \int \frac{1}{4} e^{\beta x} \{dx\} \) or equivalent.
A1 \( \frac{1}{4} xe^{\beta x} - \frac{1}{16} e^{\beta x} \) with/without + c. Can be un-simplified.

(i)sw You can ignore subsequent working following on from a correct solution.

SC SPECIAL CASE: A candidate who uses \( u = x, \frac{dv}{dx} = e^{\beta x} \), writes down the correct “by parts” formula, but makes only one error when applying it can be awarded Special Case M1.

(ii) M1 \( \pm \lambda (2x - 1)^{-2}, \lambda \neq 0 \). Note that \( \lambda \) can be 1.
A1 \( \frac{8(2x - 1)^{-2}}{(2)(-2)} \) or \( \frac{-2(2x - 1)^{-2}}{(2x - 1)^2} \) with/without + c. Can be un-simplified.

Note You can ignore subsequent working which follows from a correct answer.

(iii) B1 Separates variables as shown. \( dy \) and \( dx \) should be in the correct positions, though this mark can be implied by later working. Ignore the integral signs.

Note Allow B1 for \( \int \frac{1}{\csc 2y \csc y} = \int e^x \) or \( \int \sin 2y \sin y = \int e^x \)
M1 \( \csc 2y \rightarrow 2 \sin y \cos y \) or \( \sin 2y \rightarrow 2 \sin y \cos y \) or \( \sin 2y \sin y \rightarrow \pm \lambda \cos 3y \pm \lambda \cos y \) seen anywhere in the candidate’s working to (iii).
M1 Integrates to give \( \pm \mu \sin^3 y, \mu \neq 0 \) or \( \pm \alpha \sin 3y \pm \beta \sin y, \alpha \neq 0, \beta \neq 0 \)
A1 \( 2 \sin^2 y \cos y \rightarrow \frac{2}{3} \sin^3 y \) (with no extra terms) or integrates to give \( -\frac{1}{2} \left( \frac{1}{3} \sin 3y - \sin y \right) \)
B1 Evidence that \( e^x \) has been integrated to give \( e^x \) as part of solving their DE.

M1 Some evidence of using both \( y = \frac{\pi}{6} \) and \( x = 0 \) in an integrated or changed equation containing c.

Note that is mark can be implied by the correct value of c.
A1 \( \frac{2}{3} \sin^3 y = e^x - \frac{11}{12} \) or \( -\frac{1}{6} \sin 3y + \frac{1}{2} \sin y = e^x - \frac{11}{12} \) or any equivalent correct answer.

Note You can ignore subsequent working which follows from a correct answer.

Alternative Method 2 (Using integration by parts twice)
\[
\int \sin 2y \sin y \, dy = \int e^x \, dx
\]

\[
\frac{1}{3} \cos y \sin 2y - \frac{2}{3} \sin y \cos 2y = e^x \{ + c \}
\]

B1 oe

<table>
<thead>
<tr>
<th></th>
<th>A1 oe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applies integration by parts twice to give</td>
<td>( \pm \alpha \cos y \sin 2y \pm \beta \sin y \cos 2y )</td>
</tr>
<tr>
<td>( \frac{1}{3} \cos y \sin 2y - \frac{2}{3} \sin y \cos 2y )</td>
<td>M2</td>
</tr>
<tr>
<td>( \frac{1}{3} \cos y \sin 2y - \frac{2}{3} \sin y \cos 2y )</td>
<td>A1</td>
</tr>
<tr>
<td>(simplified or un-simplified)</td>
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<tr>
<td>( e^x \rightarrow e^x ) as part of solving their DE.</td>
<td>B1</td>
</tr>
<tr>
<td>as in the main scheme</td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>( \frac{1}{6} \sin 3y + \frac{1}{2} \sin y = e^x - \frac{11}{12} )</td>
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<tr>
<td>Question Number</td>
<td>Scheme</td>
</tr>
<tr>
<td>-----------------</td>
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<tr>
<td>7.</td>
<td></td>
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<tr>
<td>(a)</td>
<td></td>
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<tr>
<td>( x = 3 \tan \theta, \quad y = 4 \cos^2 \theta ) or ( y = 2 + 2 \cos 2\theta, \quad 0 \leq \theta &lt; \frac{\pi}{2} ).</td>
<td>( \frac{dx}{d\theta} = 3 \sec^2 \theta, \quad \frac{dy}{d\theta} = -8 \cos \theta \sin \theta ) or ( \frac{dy}{d\theta} = -4 \sin 2\theta )</td>
</tr>
</tbody>
</table>
| \( \frac{dy}{dx} = -8 \cos \theta \sin \theta \) \( \left\{ \begin{array}{c} -8 \\
\frac{\cos^3 \theta \sin \theta}{3} = -\frac{4}{3} \sin 2\theta \cos^2 \theta \end{array} \right. \) | their \( \frac{dy}{dx} \) divided by their \( \frac{dx}{d\theta} \) Correct \( \frac{dy}{dx} \) | A1 oe |
| At \( P(3, 2), \quad \theta = \frac{\pi}{4} \), \( \frac{dy}{dx} = -8 \cos \left( \frac{\pi}{4} \right) \sin \left( \frac{\pi}{4} \right) \) \( \left\{ \begin{array}{c} -8 \\
\frac{2}{3} \end{array} \right. \) | Some evidence of substituting \( \theta = \frac{\pi}{4} \) into their \( \frac{dy}{dx} \) | M1 |
| So, \( m(N) = \frac{3}{2} \) | applies \( m(N) = -\frac{1}{m(T)} \) | M1 |
| Either N: \( y - 2 = \frac{3}{2} (x - 3) \) | see notes | M1 |
| or \( 2 = \left( \frac{3}{2} \right)(3) + c \) | | |
| \{At \( Q, \quad y = 0, \) so, \( -2 = \frac{3}{2} (x - 3) \} \) giving \( x = \frac{5}{3} \) | \( x = \frac{5}{3} \) or \( 1 \frac{2}{3} \) or awrt 1.67 | A1 cso |
| \( \int y^2 \, dx = \int y^2 \frac{dx}{d\theta} \, d\theta \) \( \left\{ \begin{array}{c} \int \left( 4 \cos^2 \theta \right)^2 \sec^2 \theta \, d\theta \end{array} \right. \) | see notes | M1 |
| So, \( \pi \int y^2 \, dx = \pi \int \left( 4 \cos^2 \theta \right)^2 \sec^2 \theta \, d\theta \) | see notes | A1 |
| \( \int y^2 \, dx = \int 48 \cos^2 \theta \, d\theta \) | | |
| \( = \left\{ \begin{array}{c} 48 \int \left( \frac{1}{2} \cos 2\theta + \frac{1}{4} \sin 2\theta \right) \, d\theta \end{array} \right. \) \( = 24\theta + 12\sin 2\theta \) | | M1 |
| { dependent on the first method mark. For \( \pm \alpha \theta \pm \beta \sin 2\theta \)} | \( \cos^2 \theta \rightarrow \left\{ \begin{array}{c} \frac{1}{2} \theta + \frac{1}{4} \sin 2\theta \end{array} \right. \) | dM1 |
| \( \left\{ \begin{array}{c} = 48 \left[ \frac{1}{2} \theta + \frac{1}{4} \sin 2\theta \right]^2 \right. \end{array} \right. \) \( = 48 \left\{ \left( \frac{\pi}{8} + \frac{1}{4} \right) \right. \) \( = 0 + 0 \) \( = 6\pi + 12 \} \) | dependent on the third method mark. | dM1 |
| \{So \( V = \pi \int_0^\frac{\pi}{2} y^2 \, dx = 6\pi^2 + 12\pi \} \) | | |
| \( V_{\text{cone}} = \frac{1}{3} \pi (2)^2 \left( 3 - 3 \right) \) \( = \frac{16\pi}{9} \) \( \} \) | \( V_{\text{cone}} = \frac{1}{3} \pi (2)^2 (3 - \text{their (a)}) \) | M1 |
| \( \text{Vol}(S) = 6\pi^2 + 12\pi - \frac{16\pi}{9} \} \Rightarrow \text{Vol}(S) = \frac{92}{9} \pi + 6\pi^2 \) | | A1 |
| \( \left\{ \begin{array}{c} p = \frac{92}{9}, \quad q = 6 \end{array} \right. \) | | [9] |

15
### Question 7 Notes

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<tbody>
<tr>
<td>7. (a)</td>
<td></td>
</tr>
<tr>
<td>1st M1</td>
<td>Applies their ( \frac{dy}{d\theta} ) divided by their ( \frac{dx}{d\theta} ) or applies ( \frac{dy}{d\theta} ) multiplied by their ( \frac{d\theta}{dx} )</td>
</tr>
<tr>
<td>SC</td>
<td>Award Special Case 1st M1 if both ( \frac{dx}{d\theta} ) and ( \frac{dy}{d\theta} ) are both correct.</td>
</tr>
<tr>
<td>1st A1</td>
<td>Correct ( \frac{dy}{dx} ) i.e. ( \frac{-8 \cos \theta \sin \theta}{3 \sec^2 \theta} ) or ( \frac{8}{3} \cos \theta \sin \theta ) or ( \frac{-4}{3} \sin 2 \theta \cos \theta ) or any equivalent form.</td>
</tr>
<tr>
<td>2nd M1</td>
<td>Some evidence of substituting ( \theta = \frac{\pi}{4} ) or ( \theta = 45^\circ ) into their ( \frac{dy}{dx} ).</td>
</tr>
</tbody>
</table>

Note: For 3rd M1 and 4th M1, \( m(T) \) must be found by using \( \frac{dy}{dx} \).  
3rd M1 applies \( m(N) = \frac{-1}{m(T)} \). Numerical value for \( m(N) \) is required here.  
4th M1  
- Applies \( y - 2 = (\text{their } m_x)(x - 3) \), where \( m(N) \) is a numerical value,  
- or finds \( c \) by solving \( 2 = (\text{their } m_x)3 + c \), where \( m(N) \) is a numerical value, and \( m_x = -\frac{1}{\text{their } m(T)} \) or \( m_x = \frac{1}{\text{their } m(T)} \) or \( m_x = -\text{their } m(T) \).  

Note: This mark can be implied by subsequent working.

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<table>
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<tbody>
<tr>
<td>2nd A1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( x = \frac{5}{3} ) or ( \frac{12}{3} ) or awrt 1.67 from a correct solution only.</td>
</tr>
</tbody>
</table>

(b)  
1st M1 Applying \( \int y^2 \, dx \) as \( \int y^2 \, dx \) with their \( \frac{dx}{d\theta} \). Ignore \( \pi \) or \( \frac{1}{3} \pi \) outside integral.  
Note: You can ignore the omission of an integral sign and/or \( d\theta \) for the 1st M1.  
Note: Allow 1st M1 for \( \int (\cos^2 \theta)^2 \times \text{their } 3 \sec^2 \theta \) \( d\theta \) or \( \int 4(\cos^2 \theta)^2 \times \text{their } 3 \sec^2 \theta \) \( d\theta \) |
1st A1 Correct expression \( \left\{ \pi \int y^2 \, dx \right\} = \pi \int (4 \cos^2 \theta)^2 \times \text{their } 3 \sec^2 \theta \) \( d\theta \). (Allow the omission of \( d\theta \))  
Note: IMPORTANT: The \( \pi \) can be recovered later, but as a correct statement only.  
2nd A1 \( \left\{ \int y^2 \, dx \right\} = \int 48 \cos^2 \theta \) \( d\theta \). (Ignore \( d\theta \)). Note: 48 can be written as 24(2) for example.  
2nd M1 Applies \( \cos 2\theta = 2 \cos^2 \theta - 1 \) to their integral. (Seen or implied.)  
3rd dM1* which is dependent on the 1st M1 mark. Integrating \( \cos^2 \theta \) to give \( \pm a \theta \pm \beta \sin 2\theta \), \( a \neq 0 \), \( \beta \neq 0 \), un-simplified or simplified.  
3rd A1 which is dependent on the 3rd M1 mark and the 1st M1 mark. Integrating \( \cos^2 \theta \) to give \( \frac{1}{2} \theta + \frac{1}{4} \sin 2\theta \), un-simplified or simplified.  

This can be implied by \( k \cos^2 \theta \) giving \( \frac{k}{2} \theta + \frac{k}{4} \sin 2\theta \), un-simplified or simplified.  
4th dM1 which is dependent on the 3rd M1 mark and the 1st M1 mark. Some evidence of applying limits of \( \frac{\pi}{4} \) and 0 (0 can be implied) to an integrated function in \( \theta \)  
5th M1 Applies \( V_{cone} = \frac{1}{3} \pi (2)^3 (3 \text{ their part(a) answer}) \).  
Note: Also allow the 5th M1 for \( V_{cone} = \pi \int_{\frac{3}{2}}^{3} \left( 3x - \frac{5}{2} \right)^2 \{dx\} \), which includes the correct limits.  
4th A1 \( \frac{92}{9} \pi + 6\pi^2 \) or \( 10\frac{2}{9} \pi + 6\pi^2 \)  
Note: A decimal answer of 91.33168464... (without a correct exact answer) is A0.  
Note: The \( \pi \) in the volume formula is only needed for the 1st A1 mark and the final accuracy mark.
### Working with a Cartesian Equation

A cartesian equation for $C$ is $y = \frac{36}{x^2 + 9}$

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<th>7.</th>
<th><strong>Working with a Cartesian Equation</strong></th>
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| (a) | $1^{st}$ M1 \[
\frac{dy}{dx} = \pm \lambda \left( \pm \alpha x^2 \pm \beta \right) \quad \text{or} \quad \frac{dy}{dx} = \frac{\pm \lambda x}{\left( \pm \alpha x^2 \pm \beta \right)^2} \]
| 1$^{st}$ A1 \[
\frac{dy}{dx} = -36(x^2 + 9)^2(2x) \quad \text{or} \quad \frac{dy}{dx} = \frac{-72x}{(x^2 + 9)^2} \quad \text{un-simplified or simplified.} \]
| 2$^{nd}$ dM1 | **Dependent on the 1$^{st}$ M1 mark if a candidate uses this method**

For substituting $x = 3$ into their $\frac{dy}{dx}$

i.e. at $P(3, 2), \quad \frac{dy}{dx} = \frac{-72(3)}{(3^2 + 9)^2} \quad \left\{ \begin{array}{l}
\frac{1}{3} \end{array} \right\}$

From this point onwards the original scheme can be applied.

| (b) | $1^{st}$ M1 \[
\int \frac{\pm x}{\pm \alpha x^2 \pm \beta} \quad \text{dx} \quad (\pi \text{ not required for this mark})
\]
| $1^{st}$ A1 \[
\int \frac{36}{(x^2 + 9)^2} \quad \text{dx} \quad (\pi \text{ required for this mark})
\]
| \[
\text{To integrate, a substitution of } x = 3 \tan \theta \text{ is required which will lead to } \int 48 \cos^2 \theta d\theta \text{ and so from this point onwards the original scheme can be applied.}
\]

| (a) | $1^{st}$ M1 \[
\pm \alpha x = \pm \frac{\beta}{y^2} \quad \text{or} \quad \pm \alpha x \frac{dy}{dx} = \pm \frac{\beta}{y^2} \]
| $1^{st}$ A1 \[
2x = -\frac{36}{y^2} \frac{dy}{dx} \quad \text{or} \quad 2x \frac{dy}{dx} = -\frac{36}{y^2} \]
| $2^{nd}$ dM1 | **Dependent on the 1$^{st}$ M1 mark if a candidate uses this method**

For substituting $x = 3$ to find $\frac{dy}{dx}$

i.e. at $P(3, 2), \quad 2(3) = -\frac{36}{4} \Rightarrow \frac{dy}{dx} = ...$

From this point onwards the original scheme can be applied.
8. \( \overrightarrow{OA} = -2i + 4j + 7k \), \( \overrightarrow{OB} = -i + 3j + 8k \) & \( \overrightarrow{OP} = 0i + 2j + 3k \)
(a) \( AB = \pm ((-i + 3j + 8k) - (-2i + 4j + 7k)) = i - j + k \)

\[
\begin{align*}
\{ l_1 : \mathbf{r} \} &= \begin{pmatrix} -2 \\ 4 \\ 7 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} \quad \text{or} \quad \{ \mathbf{r} \} = \begin{pmatrix} -1 \\ 3 \\ 8 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}
\end{align*}
\]

(b) \( \overrightarrow{PB} = \overrightarrow{OB} - \overrightarrow{OP} = \begin{pmatrix} -1 \\ 3 \\ 8 \end{pmatrix} - \begin{pmatrix} 0 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} -1 \\ 1 \\ 5 \end{pmatrix} \) or \( \overrightarrow{BP} = \begin{pmatrix} 1 \\ -1 \\ -5 \end{pmatrix} \)

\[
\{ \cos \theta = \frac{\overrightarrow{AB} \cdot \overrightarrow{PB}}{||\overrightarrow{AB}|| ||\overrightarrow{PB}||} = \frac{\sqrt{1^2 + (-1)^2 + (1)^2} \cdot \sqrt{(-1)^2 + (1)^2 + (5)^2}}{\sqrt{1^2 + (-1)^2 + (1)^2} \cdot \sqrt{(-1)^2 + (1)^2 + (5)^2}} \}
\]

(c) \( \{ \cos \theta = \frac{-1-1+5}{\sqrt{3} \cdot \sqrt{27}} = \frac{3}{9} = \frac{1}{3} \} \)

Correct proof

(d) \( \{ l_2 : \mathbf{r} = \begin{pmatrix} 0 \\ 2 \\ 3 \end{pmatrix} + \mu \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix} \}
\]

(e) \( \overrightarrow{OC} = \begin{pmatrix} 0 \\ 2 \\ 3 \end{pmatrix} + \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 4 \end{pmatrix} \) or \( \overrightarrow{OD} = \begin{pmatrix} 0 \\ 2 \\ 3 \end{pmatrix} - \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} : \begin{pmatrix} C(1,1,4), D(-1,3,2) \end{pmatrix} \)

(f) \( \frac{h}{\sqrt{(-1)^2 + (1)^2 + (5)^2}} = \sin \theta \)

\( h = \sqrt{27} \sin(70.5\ldots) \) \( = \sqrt{27} \frac{\sqrt{8}}{3} = 2\sqrt{6} = \text{awrt} 4.9 \)

Area \( ABCD = \frac{1}{2} \frac{2\sqrt{6}(\sqrt{5} + 2\sqrt{3})}{\sqrt{2}} = \frac{\sqrt{2}}{2} (\text{their} \ h)(\text{their} \ AB + \text{their} \ CD) \)

\( \{ = \frac{1}{2} 2\sqrt{6}(3\sqrt{3}) = 3\sqrt{18} = 9\sqrt{2} \} \)

Way 1

\( \frac{h}{\sqrt{2}} = \frac{\sqrt{27}}{3} = \frac{9}{3} = 3. \)
8. (f) **Helpful Diagram!**

Area $\Delta APB = 4.2426...$

\[
\overrightarrow{DA} = \overrightarrow{PB} = \begin{pmatrix} \frac{-1}{2} \\ \frac{1}{4} \\ \frac{7}{2} \end{pmatrix}
\]
\[
\overrightarrow{PA} = \overrightarrow{CB} = \begin{pmatrix} \frac{-2}{2} \\ \frac{2}{4} \\ \frac{1}{2} \end{pmatrix}
\]

$\overrightarrow{PA} = \overrightarrow{CB}$ and $AB = \begin{pmatrix} \frac{1}{1} \end{pmatrix}$, so $BC \perp AB$

Candidates do not need to prove this result for part (f)

8. (f) **Way 2**

\[
h = |\overrightarrow{CB}| = \sqrt{(-2)^2 + (2)^2 + (4)^2} = \sqrt{24} = 2\sqrt{6} = 4.8989...
\]

Attempts $|\overrightarrow{PA}|$ or $|\overrightarrow{CB}|
\]
\[
|\overrightarrow{PA}| = |\overrightarrow{CB}| = \sqrt{24}
\]

\[
A_1 \text{ oe}
\]

Area $ABCD = \frac{1}{2}\sqrt{24}(\sqrt{3} + 2\sqrt{3})$ or \( \frac{1}{2}\sqrt{24}\sqrt{3} + \sqrt{24}\sqrt{3} = \frac{1}{2} h (\text{their } AB + \text{their } CD)
\]

\[9\sqrt{2}\]

8. (f) **Way 3**

Finds the area of either triangle $APB$ or $APD$ or $BCP$ and triples the result.

Area $\Delta APB = \frac{1}{2}\sqrt{3}(3\sqrt{3})\sin \theta$

\[\text{Attempts} \frac{1}{2} (\text{their } AB)(\text{their } PB)\sin \theta\]

\[\frac{1}{2}\sqrt{3}(3\sqrt{3})\sin(70.5...) \text{ or } 3\sqrt{2}\]

\[9\sqrt{2}\]

Area $ABCD = 3(3\sqrt{2})$

\[9\sqrt{2}\]
### Question 8 Notes

**8. (a)**

Finding the difference (either way) between $\overrightarrow{OB}$ and $\overrightarrow{OA}$.

If no “subtraction” seen, you can award M1 for 2 out of 3 correct components of the difference.

A1 i – j + k or $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ or (1, -1, 1) or benefit of the doubt $\begin{pmatrix} 1 \\ 1 \\ -1 \end{pmatrix}$

**B1 ft**

\[ \{ r \} = \begin{pmatrix} -2 \\ 4 \\ 7 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix} \quad \text{or} \quad \{ r \} = \begin{pmatrix} -1 \\ 3 \\ 8 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}, \text{ with } \overrightarrow{AB} \text{ or } \overrightarrow{BA} \text{ correctly followed through from (a).} \]

Note $r = \text{ is not needed.}$

(c)

An attempt to find either the vector $\overrightarrow{PB}$ or $\overrightarrow{BP}$.

If no “subtraction” seen, you can award M1 for 2 out of 3 correct components of the difference.

M1 Applies dot product formula between their $\overrightarrow{AB}$ or $\overrightarrow{BA}$ and their $\overrightarrow{PB}$ or $\overrightarrow{BP}$.

A1 Obtains $\{ \cos \theta \} = \frac{1}{3}$ by correct solution only.

Note If candidate starts by applying $\overrightarrow{AB} \cdot \overrightarrow{PB}$ correctly (without reference to $\cos \theta = ...$)

they can gain both 2nd M1 and A1 mark.

Note Award the final A1 mark if candidate achieves $\{ \cos \theta \} = \frac{1}{3}$ by either taking the dot product between

(i) $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ 5 \end{pmatrix}$ or (ii) $\begin{pmatrix} -1 \\ 1 \\ -1 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ -5 \end{pmatrix}$. Ignore if any of these vectors are labelled incorrectly.

Note Award final A0, cso for those candidates who take the dot product between

(iii) $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ -5 \end{pmatrix}$ or (iv) $\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ 5 \end{pmatrix}$

They will usually find $\{ \cos \theta \} = -\frac{1}{3}$ or may fudge $\{ \cos \theta \} = \frac{1}{3}$.

If these candidates give a convincing detailed explanation which must include reference to the direction of their vectors then this can be given A1 cso.

### Alternative Method 1: The Cosine Rule

\[ \overrightarrow{PB} = \overrightarrow{OB} - \overrightarrow{OP} = \begin{pmatrix} -1 \\ 3 \\ 8 \end{pmatrix} - \begin{pmatrix} 0 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} -1 \\ 1 \\ 5 \end{pmatrix} \quad \text{or} \quad \overrightarrow{BP} = \begin{pmatrix} 1 \\ -1 \\ -5 \end{pmatrix} \]

Mark in the same way as the main scheme.

M1

Note $|\overrightarrow{PB}| = \sqrt{27}$, $|\overrightarrow{AB}| = \sqrt{3}$ and $|\overrightarrow{PA}| = \sqrt{24}$

\[ (\sqrt{24})^2 = (\sqrt{27})^2 + (\sqrt{3})^2 - 2(\sqrt{27})(\sqrt{3})\cos \theta \]

Applies the cosine rule the correct way round

M1 oe

\[ \cos \theta = \frac{27 + 3 - 24}{18} = \frac{1}{3} \]

Correct proof

A1 cso
8. (c) **Alternative Method 2: Right-Angled Trigonometry**

\[
\vec{PB} = \vec{OB} - \vec{OP} = \begin{pmatrix} -1 \\ 3 \\ 8 \end{pmatrix} \quad \text{or} \quad \vec{BP} = \begin{pmatrix} 1 \\ -2 \\ 5 \end{pmatrix}
\]

Mark in the same way as the main scheme. M1

Either \((\sqrt{24})^2 + (\sqrt{3})^2 = (\sqrt{27})^2\)

or \(\vec{AB} \cdot \vec{PA} = \begin{pmatrix} 1 \\ -1 \\ 2 \end{pmatrix} \cdot \begin{pmatrix} 2 \\ 2 \\ 4 \end{pmatrix} = -2 - 2 + 4 = 0\) Confirms \(\triangle PAB\) is right-angled M1

So, \(\cos \theta = \frac{AB}{PB} \Rightarrow \cos \theta = \frac{\sqrt{3}}{\sqrt{27}} = \frac{1}{3}\) Correct proof A1 cso

| 3 |

(d) M1 Writing down a line in the form \(\vec{p} + \lambda \vec{d}\) or \(\vec{p} + \mu \vec{d}\) with either \(\vec{a} = \begin{pmatrix} 0 \\ 2 \\ 3 \end{pmatrix}\) or \(\vec{d} = \text{their } \overrightarrow{AB} \quad \vec{d} = \text{their } \overrightarrow{AB}\),

or a multiple of \(\overrightarrow{AB}\) found in part (a).

A1ft Writing \(2 \cdot \mu - 1 \quad \text{or} \quad 2 \cdot \mu + \vec{d}\), where \(\vec{d} = \text{their } \overrightarrow{AB} \quad \text{or a multiple of } \overrightarrow{AB}\) found in part (a).

Note \(r = \) is not needed.

Note Using the same scalar parameter as in part (b) is fine for A1.

(e) M1 Either \(\overrightarrow{OP} + \text{their } \overrightarrow{AB} \quad \text{or} \quad \overrightarrow{OP} - \text{their } \overrightarrow{AB}\).

Note This can be implied at least two out of three correct components for either their \(C\) or their \(D\).

A1ft At least one set of coordinates are correct. Ignore labelling of \(C, \ D\)

A1ft Both sets of coordinates are correct. Ignore labelling of \(C, \ D\)

Note You can follow through either or both accuracy marks in this part using their \(\overrightarrow{AB}\) from part (a).

(f) M1 Way 1: \(\frac{h}{\text{their } \overrightarrow{PB}} = \sin \theta\)

Way 2: Attempts \(|\overrightarrow{PA}| \quad \text{or} \quad |\overrightarrow{CB}|\)

Way 3: Attempts \(\frac{1}{2} (\text{their } \overrightarrow{PB})(\text{their } \overrightarrow{AB})\sin \theta\)

Note Finding \(AD\) by itself is M0.

A1 Either

- \(h = \sqrt{27} \sin(70.5...) \quad \text{or} \quad |\overrightarrow{PA}| = |\overrightarrow{CB}| = \sqrt{24} \quad \text{or equivalent.} \quad (\text{See Way 1 and Way 2})\)

or

- the area of either triangle \(\triangle APB\) or \(\triangle ABD\) or \(\triangle BDC = \frac{1}{2} \sqrt{3} (3\sqrt{3}) \sin(70.5...)\) o.e. (See Way 3).

A0 which is dependent on the 1st M1 mark.

A full method to find the area of trapezium \(ABCD\). (See Way 1, Way 2 and Way 3).

A1 9\(\sqrt{2}\) from a correct solution only.

Note A decimal answer of 12.7279... (without a correct exact answer) is A0.