



Mark Scheme (Results)

Summer 2016

Pearson Edexcel International GCSE
in Further Pure Mathematics Paper 2
(4PM0/02)

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

Summer 2016

Publications Code 4PM0_02_1606_MS

All the material in this publication is copyright

© Pearson Education Ltd 2016

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.

- **Types of mark**

- M marks: method marks
- A marks: accuracy marks. Can only be awarded if the relevant method mark(s) has (have) been gained.
- B marks: unconditional accuracy marks (independent of M marks)

- **Abbreviations**

- cao – correct answer only
- ft – follow through
- isw – ignore subsequent working
- SC - special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- eeoo – each error or omission

- **No working**

If no working is shown then correct answers may score full marks

If no working is shown then incorrect (even though nearly correct) answers score no marks.

- **With working**

If there is a wrong answer indicated always check the working and award any marks appropriate from the mark scheme.

If it is clear from the working that the “correct” answer has been obtained from incorrect working, award 0 marks.

Any case of suspected misread which does not significantly simplify the question loses two A (or B) marks on that question, but can gain all the M marks. Mark all work on follow through but enter A0 (or B0) for the first two A or B marks gained.

If working is crossed out and still legible, then it should be given any appropriate marks, as long as it has not been replaced by alternative work.

If there are multiple attempts shown, then all attempts should be marked and the highest score on a single attempt should be awarded.

- **Follow through marks**

Follow through marks which involve a single stage calculation can be awarded without working since you can check the answer yourself, but if ambiguous do not award.

Follow through marks which involve more than one stage of calculation can only be awarded on sight of the relevant working, even if it appears obvious that there is only one way you could get the answer given.

- **Ignoring subsequent work**

It is appropriate to ignore subsequent work when the additional work does not change the answer in a way that is inappropriate for the question: eg. incorrect cancelling of a fraction that would otherwise be correct.

It is not appropriate to ignore subsequent work when the additional work essentially shows that the candidate did not understand the demand of the question.

- **Linear equations**

Full marks can be gained if the solution alone is given, or otherwise unambiguously indicated in working (without contradiction elsewhere). Where the correct solution only is shown substituted, but not identified as the solution, the accuracy mark is lost but any method marks can be awarded.

- **Parts of questions**

Unless allowed by the mark scheme, the marks allocated to one part of the question CANNOT be awarded in another

General Principles for Further Pure Mathematics Marking

(but note that specific mark schemes may sometimes override these general principles)

Method mark for solving a 3 term quadratic equation:

1. Factorisation:

$$(x^2 + bx + c) = (x + p)(x + q) \text{ where } |pq| = |c|$$

$$(ax^2 + bx + c) = (mx + p)(nx + q) \text{ where } |pq| = |c| \text{ and } |mn| = |a|$$

2. Formula:

Attempt to use the **correct** formula (shown explicitly or implied by working) with values for a , b and c , leading to $x = \dots$

3. Completing the square:

$$\text{Solving } x^2 + bx + c = \left(x \pm \frac{b}{2}\right)^2 \pm q \pm c \text{ where } q \neq 0$$

Method marks for differentiation and integration:

1. Differentiation

Power of at least one term decreased by 1.

2. Integration:

Power of at least one term increased by 1.

Use of a formula:

Generally, the method mark is gained by

either quoting a correct formula and attempting to use it, even if there are mistakes in the substitution of values

or, where the formula is not quoted, the method mark can be gained by implication

from the substitution of correct values and then proceeding to a solution.

Answers without working:

The rubric states "Without sufficient working, correct answers may be awarded no marks".

General policy is that if it could be done "in your head" detailed working would not be required. (Mark schemes may override this eg in a case of "prove or show...."

Exact answers:

When a question demands an exact answer, all the working must also be exact. Once a candidate loses exactness by resorting to decimals the exactness cannot be regained.

Rounding answers (where accuracy is specified in the question)

Penalise only once per question for failing to round as instructed - ie giving more digits in the answers. Answers with fewer digits are automatically incorrect, but the isw rule may allow the mark to be awarded before the final answer is given.

| Question Number | Scheme | Marks |
|--|---|---------------------------------------|
| <p>1 (a)</p> | $\cos \theta^\circ = \frac{8^2 + 9^2 - 10^2}{2 \times 8 \times 9}$ $\theta^\circ = 71.79\dots = 71.8^\circ$ | <p>M1A1</p> <p>A1 cao (3)</p> |
| <p>(b)</p> | $\text{Area} = \frac{1}{2} ab \sin C = \frac{1}{2} \times 8 \times 9 \sin 71.79\dots$ $= 34.19\dots = 34.2 \text{ (cm}^2\text{)} \quad (\text{Use of } 71.8 \text{ also gives } 34.2)$ | <p>M1</p> <p>A1cao (2)</p> <p>[5]</p> |
| <p>(a)M1 A1 A1cao ALT:</p> | <p>Cosine rule for any angle of the triangle; can be in either form but formula must be correct Correct numbers in the cosine rule. Must be the correct angle (ie largest) Identify $\theta = 71.8^\circ$ Must be to nearest 0.1° Find at least 2 angles by cosine and possibly sine rule. (can be any 2 of the angles) M1A1 $\theta = 71.8^\circ$ Must be to nearest 0.1° A1</p> | |
| <p>(b) M1 A1cao</p> | <p>Any complete method to find the area of the triangle (use any angle found in (a) with the sides enclosing it) 34.2 Must be to 3sf unless rounding already penalised in (a)</p> | |

| Question Number | Scheme | Marks |
|--|--|--|
| <p>2 (a)</p> <p>(b)</p> <p>ALT:</p> <p>(c)</p> | $\overline{AB} = \overline{OB} - \overline{OA}, = (3\mathbf{i} + 9\mathbf{j}) - (6\mathbf{i} + 5\mathbf{j}) = -3\mathbf{i} + 4\mathbf{j}$ $\frac{\lambda}{12} = \frac{4}{(-)3}, \lambda = -16$ $\overline{PQ} = \mu \overline{AB} \quad 12\mathbf{i} + \lambda\mathbf{j} = \mu(-3\mathbf{i} + 4\mathbf{j}) \quad \text{M1 (Their } \overline{AB}) \text{ Allow } \mu = \frac{12\mathbf{i} + \lambda\mathbf{j}}{-3\mathbf{i} + 4\mathbf{j}}$ $\mu = -4 \quad \lambda = -16 \quad \text{A1}$ $ \overline{AB} = \sqrt{(3^2 + 4^2)} = 5 \text{ or } \overline{PQ} = 20$ $= \pm \frac{1}{5}(3\mathbf{i} - 4\mathbf{j}) \text{ oe}$ | <p>M1,A1cao (2)</p> <p>M1,A1cao (2)</p> <p>M1</p> <p>A1 (2)</p> <p>[6]</p> |
| <p>(a)M1</p> <p>A1cao</p> <p>(b)M1</p> <p>A1cao</p> <p>(c)M1</p> <p>A1</p> | <p>$\overline{AB} = \overline{OB} - \overline{OA}$ or $\overline{OB} + \overline{AO}$ or use a diagram. Column vectors allowed for the M mark.</p> <p>$-3\mathbf{i} + 4\mathbf{j}$ or $4\mathbf{j} - 3\mathbf{i}$ or $\begin{pmatrix} -3\mathbf{i} \\ 4\mathbf{j} \end{pmatrix}$ but \mathbf{i}, \mathbf{j} must be included</p> <p>Finding and equating the gradients of the two lines. Fractions can be either way up as long as consistent and attempting to solve for λ There may be sign errors in the equation. Or compare the components.</p> <p>NB: Using $\overline{PQ} = \overline{AB}$ scores M0 unless a fresh start is made.</p> <p>$\lambda = -16$</p> <p>Use Pythagoras with a + sign to obtain the length of their AB or their PQ</p> <p>A correct unit vector in either direction and any equivalent form inc column vector</p> | |

| Question Number | Scheme | Marks |
|--|--|---|
| <p>3 (a)</p> <p>(b)</p> <p>(c)</p> | $\frac{(5x+3)}{(11x-3)} = \frac{(3x-3)}{(5x+3)} \text{ or } (5x+3)^2 = (3x-3)(11x-3)$ $25x^2 + 30x + 9 = 33x^2 - 42x + 9$ $8x^2 - 72x (= 0) \quad x = 0, x = 9$ <p>Spec case: Give M1A0M0A0 (ie B1) if $x = 0$ seen w/o working</p> <p>$x = 0 \quad r = \frac{3}{-3} = -1$</p> <p>$x = 9 \quad r = \frac{48}{96} = \frac{1}{2}$</p> <p>$x = 9 \quad a = 96$</p> $S_{\infty} = \frac{96}{1 - \frac{1}{2}} = 192$ | <p>M1A1</p> <p>dM1A1 (4)</p> <p>B1</p> <p>M1A1cso (3)</p> <p>M1Aft, A1cao (3)</p> <p>[10]</p> |
| <p>(a)M1</p> <p>A1</p> <p>dM1</p> <p>A1</p> <p>(b)</p> <p>B1</p> <p>M1</p> <p>A1cso</p> <p>(c)M1</p> <p>A1ft</p> <p>A1cao</p> | <p>Form an equation connecting the three given terms, must either be equating fractions or multiplying in pairs.</p> <p>Correct equation, fractions can be either way up</p> <p>Solve the resulting quadratic to $x = \dots$</p> <p>Both correct values of x obtained</p> <p>$r = -1$ seen</p> <p>Use a non-zero value of x obtained in (a) and obtain the corresponding of r. Must use the same value of x in both substitutions.</p> <p>$r = \frac{1}{2}$</p> <p>Use the formula for the sum to infinity of a convergent geometric series with $r < 1$ and a value of a found using the corresponding value of x.</p> <p>Acceptable formulae $S_{\infty} = \frac{a}{1-r}, = \frac{a(1-r^{\infty})}{1-r}, = \frac{a(r^{\infty}-1)}{r-1}$</p> <p>"Correct" numbers in the formula, ft their x and r and $r^{\infty} = 0$</p> <p>192</p> | |

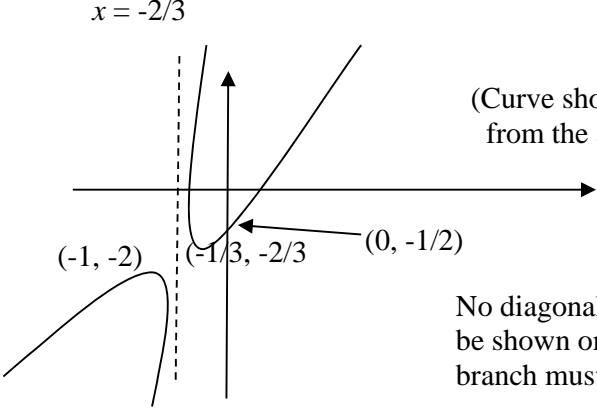
| Question Number | Scheme | Marks |
|--|---|---------------|
| 4 | $\frac{dy}{dx} = 2e^{2x} \cos 3x - 3e^{2x} \sin 3x$ | M1A1A1 [3] |
| M1 A1 A1 NB | Differentiate wrt x . Two terms either added or subtracted. Terms to be one of each of $pe^{2x} \cos 3x$ and $qe^{2x} \sin 3x$ where p and q are integers. Either term correct The other term correct If the product rule is quoted and brackets omitted on application eg $2e^{2x} \cos 3x + e^{2x} - 3 \sin 3x$ allow for "invisible brackets" and award M1A1A0. If final statement fully correct award M1A1A1 | |

| Question Number | Scheme | Marks |
|--|---|---|
| <p>5(a)</p> <p>(b)</p> <p>(c)</p> | $V = x \times 4x \times h = 772$ $h = \frac{193}{x^2} = \frac{772}{4x^2}$ $A = 2 \times 4x^2 + 2xh + 2 \times 4xh = 8x^2 + 10xh$ $A = 8x^2 + 10x \times \frac{193}{x^2} = 8x^2 + \frac{1930}{x} \quad *$ <p>(b)</p> $(A =) 8x^2 + 1930x^{-1}$ $\left(\frac{dA}{dx} =\right) 16x - 1930x^{-2}$ $\left(\frac{dA}{dx} = 0 \Rightarrow\right) 16x = \frac{1930}{x^2}$ $x^3 = \frac{1930}{16} \quad x = 4.9409... = 4.94$ $\left(\frac{d^2A}{dx^2} =\right) 16 + 3860x^{-3}$ $x = 4.94 \Rightarrow \frac{d^2A}{dx^2} > 0 \quad \therefore \text{minimum}$ <p>(c)</p> $A_{\min} = 8 \times 4.940...^2 + \frac{1930}{4.940...} = 585.9..., = 586$ | <p>B1</p> <p>M1A1cso (3)</p> <p>M1</p> <p>dM1</p> <p>A1</p> <p>M1</p> <p>A1ft (5)</p> <p>M1,A1cao (2)</p> <p>[10]</p> |
| <p>(a)B1</p> <p>M1</p> <p>A1cso</p> <p>(b)</p> <p>M1</p> <p>dM1</p> <p>A1</p> <p>M1</p> <p>A1ft</p> <p>ALTs</p> <p>(c)</p> <p>M1</p> <p>A1cao</p> | <p>$h = \frac{193}{x^2}$ or $\frac{772}{4x^2}$ or $xh = \frac{193}{x}$ oe Seen explicitly or used in the expression for A</p> <p>Form an expression for A in terms of x and h which must be dimensionally correct and replace h with a function of x</p> <p>Obtain the given expression for A. No errors seen. Must start A = ... or area = ...</p> <p>Differentiate the GIVEN expression for A</p> <p>Equate their derivative to 0. Dependent on the previous M mark.</p> <p>$x = 4.94$ Must be 3 sf</p> <p>Special Case: 4.94 with no working (calculator solution) scores M1M1A1</p> <p>Attempt the second derivative - must have 2 terms.</p> <p>Deduce that their value of x gives a minimum, follow through their x. No need to evaluate the derivative provided the value of x is positive and the derivative is algebraically correct. Must have a conclusion.</p> <p>For last 2 marks: Look at signs of $\frac{dA}{dx}$ either side of $x = 4.94$ and calculate the values of $\frac{dA}{dx}$ (M1) All correct with conclusion (A1) or refer to the graph - sketch must be shown.</p> <p>Use their value of x in the given expression for A and complete to A = ...</p> <p>586 Must be 3sf unless rounding already penalised in (b)</p> | |

| Question Number | Scheme | Marks |
|---|---|---|
| <p>6 (a)</p> <p>(b)</p> | $5x + 4 = x^2 + 2x - 6$ $x^2 - 3x - 10 (= 0)$ $(x - 5)(x + 2) (= 0)$ $x = 5 \quad y = 29; \quad x = -2 \quad y = -6$ $\int_{-2}^5 ((5x + 4) - (x^2 + 2x - 6)) dx \quad \text{(either way round)}$ $\int_{-2}^5 (-x^2 + 3x + 10) dx$ $\left[-\frac{1}{3}x^3 + \frac{3}{2}x^2 + 10x \right]_{-2}^5 \quad \text{(Correct integration of a function, either way round or correct integration of two sep functions)}$ $= \left(-\frac{125}{3} + \frac{75}{2} + 50 \right) - \left(\frac{8}{3} + 6 - 20 \right)$ $= 57\frac{1}{6}, \frac{343}{6} \quad \text{must be positive}$ | <p>M1</p> <p>A1</p> <p>M1A1A1 (5)</p> <p>M1</p> <p>M1A1</p> <p>dM1</p> <p>A1cao (5)</p> <p>[10]</p> |
| <p>(a)</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>A1</p> <p>A1</p> <p>NB</p> <p>(b)</p> <p>M1</p> <p>M1</p> <p>A1</p> <p>dM1</p> <p>A1cao</p> <p>NB</p> | <p>Eliminate y or x between the two equations to obtain an equation in a single variable</p> <p>Correct 3 term quadratic</p> <p>Solve their 3TQ to $x = \dots$ or $y = \dots$. Calculator solutions must have $x = -2$ and 5 or $y = -6$ and 29 ie both solutions for their variable.</p> <p>Either pair of coordinates correct</p> <p>Second pair correct. Coordinate brackets not needed but some indication of pairing is needed</p> <p>Table of values methods score 0/5</p> <p>For the integral of "line - curve", either way round. Ignore any limits shown. This mark can be given later if two separate integrals are used - give when the difference of the two integrals is shown.</p> <p>Integration of the function, either way round or correct integration of two separate functions</p> <p>Correct integration. Ignore limits for these two marks.</p> <p>Substitute their limits (ie their values found in (a)) in the integral of the single function or in both integrals. Both the above M marks must be earned.</p> <p>Area = $57\frac{1}{6}$ oe must be positive.</p> <p>If only the line or the curve is integrated score is 0/5</p> | |

| Question Number | Scheme | Marks |
|-----------------|---|--|
| 7(a) | $\frac{dv}{dt} = 6t - 4$ $t = 2 \quad \text{accel} = 8 \text{ (m/s}^2\text{)}$ | M1 A1 (2) |
| (b) | $v \text{ is min when } \frac{dv}{dt} = 0 \text{ ie when } t = \frac{2}{3}$ $v_{\min} = 3 \times \left(\frac{2}{3}\right)^2 - 4 \times \frac{2}{3} + 7 = 5\frac{2}{3} \text{ (m/s) (Accept 5.67, } \frac{17}{3}\text{)}$ | M1 M1A1 (3) |
| (c) | $V = 7$ | B1 (1) |
| (d) | $3t^2 - 4t + 7 = 7$ $t(3t - 4) = 0 \quad (t = 0) \quad t = \frac{4}{3}$ $AB = \int_0^{\frac{4}{3}} (3t^2 - 4t + 7) dt$ $= \left[t^3 - 2t^2 + 7t \right]_0^{\frac{4}{3}}$ $= \left(\frac{4}{3}\right)^3 - 2 \times \left(\frac{4}{3}\right)^2 + 7 \times \frac{4}{3} \quad (-0)$ $= 8\frac{4}{27} \text{ (m), } \frac{220}{27} \text{ (Accept 8.15 or better)}$ | B1 M1 M1A1 dM1 A1cao,cso (6) [12] |

| | |
|--------------|---|
| (a) | |
| M1 | Differentiate given expression for v wrt t . Power must decrease on at least one term |
| A1 | Substitute $t = 2$ and obtain accel = 8 (m/s ²) |
| | Correct answer with no working shown Award both marks |
| (b) | |
| M1 | Set their $\frac{dv}{dt} = 0$ and solve to $t = \dots$ or deduce the nec value of t from work in (a) |
| M1 | Substitute their value of t in the GIVEN expression for v |
| A1 | $5\frac{2}{3}$ or $\frac{17}{3}$ or 5.67 Decimal to be 3 sf or better |
| | Correct answer with no working Award 3/3 |
| ALT | Complete the square on v $v = 3\left(t - \frac{2}{3}\right)^2 + 7 - \dots$ M1 |
| | Identify the constant " $7 - \frac{4}{3}$ " as the min or take $t = \frac{2}{3}$ from bracket and substitute M1 |
| | Correct answer A1 |
| (c) | |
| B1 | ($V =$)7 Need not say $V =$ |
| (d) | |
| B1 | Equate the expression for v to 7 and solve to obtain $t = 4/3$ No need to show $t = 0$ |
| M1 | Form the required integral with lower limit = 0 and their value of t as the upper limit |
| | Do NOT give this mark until limits are seen. |
| M1 | Attempt the integration. Power to increase on at least one term. |
| A1 | Correct integration |
| dM1 | Substitute their upper limit in a changed function. Depends on the first M mark but not the second. Sub of lower limit need not be seen (it gives 0) |
| A1cao | $8\frac{4}{27}$ or $\frac{220}{27}$ Decimal to be 3 sf or better |
| cso | |
| ALT: | By Indefinite integration: B1 As above; M1 Do NOT award until $t = 0$ is used to find the constant of integration M1A1 for the integration constant can be omitted dM1A1 as above |

| Question Number | Scheme | Marks |
|-----------------|---|---|
| 8(a) | $x = -\frac{2}{3}$ | B1 (1) |
| (b) | $\frac{dy}{dx} = \frac{6x(3x+2) - 3(3x^2 - 1)}{(3x+2)^2}$ $18x^2 + 12x - 9x^2 + 3 = 0 \quad \text{oe}$ $3x^2 + 4x + 1 = 0$ $(3x+1)(x+1) = 0 \quad x = -\frac{1}{3} \quad x = -1$ $\left(-\frac{1}{3}, -\frac{2}{3}\right) \quad (-1, -2)$ | M1A1A1 M1 A1 M1A1 A1 (8) |
| (c) | A is $\left(0, -\frac{1}{2}\right)$ | B1 (1) |
| (d) |  | B1 two branches with turning points B1 Asymptote parallel to y-axis B1 Required coords (3) |
| (e) | $\text{grad at A} = \frac{0 - 3(-1)}{2^2} = \frac{3}{4} \quad \text{grad normal} = -\frac{4}{3}$ $y + \frac{1}{2} = -\frac{4}{3}x \quad \text{oe}$ | B1 M1A1 (3) [16] |

8(a)**B1** $x = -\frac{2}{3}$ oe eg $3x = -2$, $3x + 2 = 0$ Must be an equation**(b)****M1** Attempt to differentiate using the quotient or product rule.For quotient rule, the numerator must be the difference of 2 terms and the denominator must be $(3x+2)^2$ For the product rule the difference of 2 terms is required and both terms must contain $(3x+2)^{-k}$, where $k = 1$ or 2 **A1** For quotient rule, either term correct apart from sign

For product rule, either term correct

A1 Completely correct derivative.**M1** Equate their numerator to 0. (For product rule use, equate their whole derivative to 0)**A1** Simplify to the correct 3 term quadratic. Terms can be in any order.**M1** Attempt the solution of their 3 term quadratic**A1** **Two** correct values for x **A1** Corresponding correct values for y . No need to write in coordinate brackets.**(c)****B1** $\left(0, -\frac{1}{2}\right)$ or $x = 0, y = -\frac{1}{2}$ **(d)****B1** Two branches with turning points. One to be in all 4 quadrants, the other in the third quadrant only**B1** Vertical asymptote drawn and labelled either with its equation or by the point where it crosses the x -axis. At least one branch of the curve must be asymptotic to the line and neither branch should cross it.**B1** Show the required coordinates on their sketch beside their turning points or indicated by arrow(s).**(e)****B1** Gradient of the normal seen explicitly or used.**M1** Any **complete** method for the equation of a line using their gradient of the normal at A and their coordinates of A **A1** Correct equation, any equivalent form.

| Question Number | Scheme | Marks |
|-----------------|--|---------------|
| 9 | | |
| (a) | $\cos(\theta + \theta) = \cos \theta \cos \theta - \sin \theta \sin \theta$ | M1 |
| | $\cos 2\theta = \cos^2 \theta - (1 - \cos^2 \theta)$ | M1 |
| | $\cos 2\theta = 2\cos^2 \theta - 1$ * | A1cso (3) |
| (b) | $\sin 2\theta = 2\sin \theta \cos \theta$ | B1 (1) |
| (c) | $\cos 3\theta = \cos 2\theta \cos \theta - \sin 2\theta \sin \theta$ | M1 |
| | $= (2\cos^2 \theta - 1)\cos \theta - 2\sin \theta \cos \theta \sin \theta$ | M1 |
| | $= 2\cos^3 \theta - \cos \theta - 2(1 - \cos^2 \theta)\cos \theta$ | M1 |
| | $= 4\cos^3 \theta - 3\cos \theta$ * | A1cso (4) |
| (d) | $1 = 8\cos^3 \theta - 6\cos \theta = 2\cos 3\theta$ | |
| | $\cos 3\theta = \frac{1}{2}$ | M1 |
| | $3\theta = \frac{\pi}{3}, \frac{5\pi}{3}, \frac{7\pi}{3}$ | M1 |
| | $\theta = \frac{\pi}{9}, \frac{5\pi}{9}, \frac{7\pi}{9}$ | A1A1 (4) |
| (e) | $\int (8\cos^3 \theta + 4\sin \theta) d\theta = \int (2\cos 3\theta + 6\cos \theta + 4\sin \theta) dx$ | M1 |
| | $= \frac{2}{3}\sin 3\theta + 6\sin \theta - 4\cos \theta (+c)$ | A1 |
| (ii) | $= \frac{2}{3}\sin \pi + 6\sin \frac{\pi}{3} - 4\cos \frac{\pi}{3} - (-4\cos 0)$ | dM1 |
| | $= 6 \times \frac{\sqrt{3}}{2} - 2 + 4 = 3\sqrt{3} + 2$ | A1cao cso (4) |
| | | [16] |

| | |
|----------|--|
| 9 | If c, s used for cos and sin allow for all marks except final A marks in each section. For these marks the candidate must return to cos, sin as appropriate. |
| (a) | |
| M1 | Replace A and B with θ in $\cos(A+B) = \cos A \cos B - \sin A \sin B$ |
| M1 | Use $\sin^2 \theta = 1 - \cos^2 \theta$ to eliminate $\sin^2 \theta$ |
| A1cso | Obtain the given identity with no errors seen |
| (b) | |
| B1 | $\sin 2\theta = 2 \sin \theta \cos \theta$ Must be simplified |
| (c) | |
| M1 | Use $\cos(A+B) = \cos A \cos B - \sin A \sin B$ with $A = 2\theta$, $B = \theta$ to eliminate 3θ |
| M1 | Use $\cos 2\theta = 2 \cos^2 \theta - 1$ and $\sin 2\theta = 2 \sin \theta \cos \theta$ to obtain an expression with powers of $\sin \theta$ and $\cos \theta$ |
| M1 | Use $\sin^2 \theta = 1 - \cos^2 \theta$ to eliminate $\sin^2 \theta$ leaving powers of cos only |
| A1cso | Obtain the given identity with no errors seen |
| (d) | |
| M1 | Use the identity given in (c) to change the equation to the form $\cos 3\theta = k$ where $-1 < k < 1$ |
| M1 | Obtain 1 value in range $0, 3\theta < 3\pi$ in terms of π for 3θ |
| A1 | Any 2 correct values for θ |
| A1 | Third correct value for θ Ignore any answers outside the range, deduct one A mark if extras within the range are included. |
| ALT: | Can work in degrees for the M marks; A marks only available if answers changed to radians without loss of accuracy. |
| (e) | |
| (i) M1 | Change the given integrand to one which can be integrated, either by using the identity in (c) or by obtaining $\int (8 \cos^3 \theta + 4 \sin \theta) d\theta = \int (8(1 - \sin^2 \theta) \cos \theta + 4 \sin \theta) dx$ |
| A1 | Correct integration $\frac{2}{3} \sin 3\theta + 6 \sin \theta - 4 \cos \theta (+c)$ or $8 \sin \theta - \frac{8}{3} \sin^3 \theta - 4 \cos \theta (+c)$ |
| (ii) dM1 | Constant of integration may be missing. Substitute both limits into their answer from (i)- evidence needed of substitution of 0 Substitution of upper limit followed by - 0 qualifies |
| A1cao | $3\sqrt{3} + 2$ oe two terms only. |
| cso | |
| | Watch for: |
| | $\int (8 \cos^3 \theta + 4 \sin \theta) d\theta = \left[8 \sin^3 \theta - 4 \cos \theta \right]_0^{\frac{\pi}{3}}$ |
| | $= 3\sqrt{3} - 2 - (-4)$ |
| | $=$ correct answer !! |
| | But from completely INCORRECT working. |

| Question Number | Scheme | Marks |
|-----------------|---|---|
| 10(a) | $V = \frac{1}{3} \pi h r^2 = \frac{1}{3} \pi h \times (h \tan 30)^2 \left(= \frac{1}{3} \pi h^3 \times \left(\frac{1}{\sqrt{3}} \right)^2 = \frac{1}{9} \pi h^3 \right)$ $V = 0.4t$ $0.4t = \frac{2}{5} t = \frac{1}{9} \pi h^3$ $h^3 = \frac{18t}{5\pi} *$ | B1 B1 M1 A1cso (4) |
| (b) | $\text{Area of top} = \pi (h \tan 30)^2 = \frac{1}{3} \pi h^2$ $\frac{dA}{dh} = \frac{2}{3} \pi h$ $\frac{dA}{dt} = \frac{dA}{dh} \times \frac{dh}{dt}$ $h^3 = \frac{18t}{5\pi}$ $3h^2 = \frac{18}{5\pi} \frac{dt}{dh}$ $\frac{dh}{dt} = \frac{6}{5\pi h^2}$ $\frac{dA}{dt} = \frac{2}{3} \pi h \times \frac{6}{5\pi h^2} = \frac{4}{5h} *$ | B1 M1 M1 M1 A1 A1cao (6) |
| (c) | $t = 10 \quad h = \sqrt[3]{\frac{180}{5\pi}} \quad \frac{dA}{dt} = \frac{4}{5h} = 0.355 \text{ cm}^2/\text{s}$ | M1A1cao (2) [12] |

| | |
|-----------------------|---|
| <p>10(a)B1</p> | <p>$V = \frac{1}{3}\pi h \times (h \tan 30)^2$ (or $V = \frac{1}{9}\pi h^3$) (ie replace r)</p> |
| <p>B1</p> | <p>$V = 0.4t$</p> |
| <p>M1</p> | <p>Equating their 2 expressions for V to obtain an equation without r</p> |
| <p>A1cso</p> | <p>Re-arrange to $h^3 = \frac{18t}{5\pi}$ with no errors seen</p> |
| <p>(b)</p> | |
| <p>B1</p> | <p>Area of top = $\frac{1}{3}\pi h^2$</p> |
| <p>M1</p> | <p>Differentiate their expression for the area of the top wrt h</p> |
| <p>M1</p> | <p>Chain rule connecting $\frac{dA}{dt}$, $\frac{dA}{dh}$ and $\frac{dh}{dt}$, any equivalent form or a useful chain rule with more derivatives eg $\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dh} \times \frac{dh}{dt}$ see alt solution below</p> |
| <p>M1</p> | <p>Differentiate the given expression from (a) wrt h or t</p> |
| <p>A1</p> | <p>$\frac{dh}{dt} = \frac{6}{5\pi h^2}$ or $\frac{dt}{dh} = \frac{5\pi h^2}{6}$ or any equivalent expression in terms of t.</p> |
| <p>A1cao</p> | <p>Substitute for $\frac{dA}{dh}$ and $\frac{dh}{dt}$ in the chain rule to obtain the given expression for $\frac{dA}{dt}$ No errors seen.</p> |
| <p>ALTs:</p> | |
| <p>1</p> | <p>Using $\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dh} \times \frac{dh}{dt}$</p> |
| <p>B1</p> | <p>$\frac{dA}{dr} = 2\pi r$ M1 Find $\frac{dr}{dh} = \frac{1}{\sqrt{3}}$ M1 Chain rule $\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dh} \times \frac{dh}{dt}$</p> |
| <p>M1A1A1</p> | <p>As main scheme</p> |
| <p>2</p> | <p>Using $\frac{dA}{dt} = \frac{dA}{dh} \times \frac{dh}{dV} \times \frac{dV}{dt}$</p> |
| <p>B1M1</p> | <p>As main scheme M1 Chain rule $\frac{dA}{dt} = \frac{dA}{dh} \times \frac{dh}{dV} \times \frac{dV}{dt}$</p> |
| <p>M1</p> | <p>Attempt $\frac{dV}{dh}$ using their expression for V in terms of h found in (a)</p> |
| <p>A1</p> | <p>$\frac{dV}{dt} = 0.4$ A1 Complete to required result.</p> |
| <p>3</p> | <p>Using $\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dt}$</p> |
| <p>B1</p> | <p>$\frac{dA}{dr} = 2\pi r$ M1 $t = \frac{5}{6}\pi r^2 h$ (Obtained from $0.4t = \frac{1}{3}\pi r^2 h$ (in (a)))</p> |
| <p>M1</p> | <p>$\frac{dt}{dr} = \frac{5\sqrt{3}}{2}\pi r^2$ M1 $\frac{dA}{dt} = \frac{dA}{dr} \times \frac{dr}{dt} \left(= 2\pi r \times \frac{2}{5\sqrt{3}\pi r} = \frac{4}{5\sqrt{3}r} \right)$</p> |
| <p>A1</p> | <p>Use $h = \sqrt{3}r$ in their $\frac{dA}{dt}$ A1 Correct final result, no errors seen</p> |

| | |
|--------------|--|
| (c) | |
| M1 | Use $t = 10$ to obtain the corresponding value of h $h = \left(\sqrt[3]{\frac{180}{5\pi}} \text{ or } 2.2545\dots \right)$ and substitute their value of h in the expression from (b) to obtain $\frac{dA}{dt} = \dots$ |
| A1cao | $\frac{dA}{dt} = 0.355 \text{ (cm}^2\text{/s)}$ Must be 3sf. |

