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Mark Scheme

Summer 2023

Pearson Edexcel GCE

A2 Mathematics (9MA0)

Paper 02 Pure Mathematics

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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.
* When examiners are in doubt regarding the application of the mark scheme to a candidate’s response, the team leader must be consulted.
* 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 100.
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.

1. 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 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

1. 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.
2. Where a candidate has made multiple responses and indicates which response they wish to submit, examiners should mark this response.

If there are several attempts at a question which have not been crossed out, examiners should mark the final answer which is the answer that is the most complete.

1. Ignore wrong working or incorrect statements following a correct answer.
2. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

**General Principles for Pure Mathematics Marking**

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

**Method mark for solving 3 term quadratic:**

1. Factorisation

, leading to *x* = …

, leading to *x* = …

2. Formula

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

3. Completing the square

Solving : , leading to *x* = …

**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**

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 mistakes 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.

**Answers without working**

The rubric says that these may not gain full credit. Individual mark schemes will give details of what happens in particular cases. General policy is that if it could be done “in your head”, detailed working would not be required. Most candidates do show working, but there are occasional awkward cases and if the mark scheme does not cover this, please contact your team leader for advice.

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| --- | --- | --- | --- |
| **Question** | **Scheme** | **Marks** | **AOs** |
| **1(a)** |  | **M1** | 1.1b |
|  | **A1cso** | 1.1b |
|  | **(2)** |  |
| **(b)(i)**  **(ii)** |  | **B1ft** | 1.1b |
| or | **B1ft** | 2.2a |
|  | **(2)** |  |
| **(4 marks)** | | | |
| **Notes** | | | |
| **(a)**  **M1:** For attempting to differentiate twice.  It can be scored for any of:  or  or  where … are  constants.  You can ignore the lhs so do not be concerned what they call the first and/or second derivative, just look  for their expressions.  The indices do not need to be processed for this mark so allow for e.g.  **A1cso:**  Correct second derivative from fully correct work. The  is not required.  Allow  for 6 *x* but not  for 4 unless the  becomes 4 later, e.g. in part (b).  Do **not** apply isw so mark their final answer. E.g. if 6 *x* + 4 becomes 3 *x* + 2 score A0 | | | |
| **(b)**  **(i)**  **B1ft:**  This mark is for obtaining  **or**  which has come from solving an  equation of the form  where *ax* + *b* is their attempt to differentiate twice in part (a)  Allow equivalent fractions e.g.  or equivalents for their  or an exact decimal and isw.  **(ii)**  **B1ft:** Deduces   **or** follow through their single value of *x* from part (i) obtained from their attempt to  solve an equation of the form  where *ax* + *b* was their attempt to differentiate  twice in part (a) . Do not isw and mark their final answer.  If 2 inequalities are given e.g.  without indicating which is their answer score B0  Condoneand allow equivalent inequalities e.g.  Allow equivalent fractions e.g.  or equivalents for their  Allow equivalent notation so these are all acceptable:    Ignore any reference to values of *y*.  Allow ft decimal answers from (i) which may be inexact.  Correct answers in part (b) with no working in (a) can score 0011. | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **2(a)(i)**  **(ii)** | e.g.  \* | **B1\*** | 2.1 |
| **or** | **M1** | 1.1b |
|  | **A1** | 1.1b |
|  | **(3)** |  |
| **(b)(i)**  **(ii)** |  | **B1** | 2.2a |
| e.g. | **M1** | 3.1a |
| = 851 | **A1** | 1.1b |
|  | **(3)** |  |
| **(6 marks)** | | | |
| **Notes** | | | |
| **(a)**  **(i)**  **B1\*:** **Correct** application of the formula with *n* = 1 and proceeds correctly to achieve an answer of 40 with  no errors. Note that e.g.,  scores B0  As a minimum need to see e.g.  **(ii)**  **M1:** A correct attempt to use the formula to find a value for  or  Look for *n* = 2 substituted correctly into the given formula with . May be implied by  Or their calculated value of used with *n* = 3 substituted correctly into the given formula to find  Condone use of calculator in degree mode which gives  which may imply this mark if no  working is shown. If there is **no** working and  is incorrect and is correct score M0A0  **A1:** Both correct  If 28, 33 are listed then allow M1A1.  **For both correct values only score M1A1** | | | |
| **(b)(i)**  **B1:**  **(ii)**  **M1:** Attempts a **correct** method to find  There are various ways e.g. attempts to add 35 to the sum of their four values.  Some other examples are:  ,    There may be other methods seen but the calculation must be correct for their values.  If there is no working, with incorrect  you will need to check if their answer implies a  correct method using  Attempts to use an AP/GP formula score M0  **A1:** 851 (Correct answer with no working scores both marks) | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **3(a)** | Uses one correct log law e.g. | **M1** | 1.1b |
| oe | **dM1** | 2.1 |
| \* | **A1\*** | 1.1b |
|  | **(3)** |  |
| **(b)(i)**  **(ii)** |  | **B1** | 1.1b |
| because  is not real | **B1** | 2.4 |
|  | **(2)** |  |
| **(5 marks)** | | | |
| **Notes** | | | |
| **(a)**  **M1:** Uses one correct log law. The base does not need to be seen for this mark.  This mark is independent of any other errors they make.  Examples:  **dM1:** Fully correct work leading to a correct equation not containing logs that is not the printed answer.  **Depends on the first mark.** Condone a spurious base e.g. 10 or e, so long as the log work is  otherwise correct (i.e., they recover the base 2).  Examples (depending on their method):  or  Allow recovery from invisible brackets but **not** from incorrect work e.g.      This scores M1dM0A0  **A1\*:** Obtains  with no processing errors but condone a spurious base e.g. 10 or e, so long  as the log work is otherwise correct (i.e., they recover the base 2) and allow recovery from invisible  brackets.  **Note the following alternative which can follow the main scheme:**  **M1**  **dM1**  \* **A1**  **Special Cases:**  **1.**  with no working leading to the correct answer scores **M1dM1A0**  **2.**  \*  Also scores **M1(implied)dM1A0** (lack of working)  **(b)(i)**  **B1:** Both values correct:  **(b)(ii)**  **B1:** e.g.  and  is not real  This mark requires the identification of the **correct** negative root **and** an acceptable explanation.  For the identification of the root allow e.g.  etc. as long as it is clear they have  identified the correct value. Requires the correct negative root  but the other may not be 6 but  must be positive.  Some examples for the explanation:   * you get  which is not possible * is not possible, can’t be found, gives a math error, is not real, is undefined * if  which is not possible * you get log of a negative number * negative numbers can’t be “logged” * log of negative does not work   Do not allow e.g.   * you can’t have a negative log, logs can’t be negative (unless clarified further) * “you get a math error” in isolation * a log cannot have a negative value * logs cannot be negative * is not a valid input (unless clarified further) * “it doesn’t work in the logs” * log graph isn't negative * log graph does not cross negative *x*–axis * *x* is only positive & negative answer does not work   Allow an implied correct answer if they say e.g. 6 is the root because  is not possible | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **4(a)** |  | **B1** | 3.4 |
|  | **(1)** |  |
| **(b)** | or | **M1** | 3.1b |
|  | **M1** | 1.1b |
|  | **A1cso** | 3.3 |
|  | **(3)** |  |
| **(4 marks)** | | | |
| **Notes** | | | |
| **(a)**  **B1:** 55 only. Just look for this value e.g. “*A* =” is not required. Ignore any “units” if given e.g. 55 °C  **(b)**  **M1:** Differentiates to obtain an expression of the form  which may have their *A* already substituted  in so allow for  or  **M1:** Substitutes *t* = 0 andtheir *A* into their sets  and proceeds to find a value for *B* which  may be implied by  Their  must not be *H*. i.e. it must be a “changed” function.  **A1cso:** Correct **equation** which follows **fully correct work**  but condone  The final equation must be correct but you can ignore spurious notation within their solution such as  integral signs and “+ *c*” which do not affect their solution.  **Marking guidance is as follows for particular cases in (b)**  Case 1:  scores **M1M1A0**  **Error: it should be – 7.5**  Case 2:  scores **M1M1A0**  **Error: incorrect derivative**  Case 3:  scores **M1M1A0**  **Error: incorrect derivative**  Case 4:  scores **M1M1A1**  **No errors** | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **5(a)** |  | **M1** | 1.1b |
| or | **A1\*** | 1.1b |
|  | **(2)** |  |
|  | **(a) Alternative by verification:** |  |  |
|  |  | **M1** | 1.1b |
|  | Hence *k* = 12 \* | **A1\*** | 1.1b |
|  |  | **(2)** |  |
| **(b)** |  | **M1** | 3.1a |
|  | **dM1** | 1.1b |
|  | **A1** | 2.2a |
|  | **(3)** |  |
| **(5 marks)** | | | |
| **Notes** | | | |
| **(a) Mark (a) and (b) together**  **M1:** Substitutes *x* = 3 completely into the given derivative, sets = 0 and solves for *k*.  e.g.,  May be implied by e.g. with at least 2 correctly evaluated powers.  **A1\*:** Obtains *k* = 12 with no errors seen and sufficient working shown. As a minimum you would need to  see e.g.,**or**  **or**  But  scores M1A0 for lack of working  Note that some are just writing the expression for , then write “sub in *x* = 3” but don't actually show 3 substituted in and then go on to write  leading to scores M0A0\*.  **Alternative:**  **M1:** Substitutes *x* = 3 and *k* = 12 into the given derivative and attempts to evaluate  **A1\*:** Correct work to obtain an answer of 0 with a (minimal) conclusion e.g., tick, hence proven etc.  As a minimum you would need to see e.g., ✓  **(b)**  **M1:** Attempts to integrate. Evidence can be taken for integrating to obtain at least 2 from:  where … are constants  **dM1:** Substitutes *x* = 3 into their integrated expression that includes a constant of integration, sets this equal  to ±10 and proceeds to find their constant*.* **Depends on the previous mark.**  If the substitution is not shown this mark may be implied by their value for *c* or by their  equation e.g.,  **A1:**  Condone  or *y* =  but not just *c* = −28. There must be no other values or points.  Condone  following *y* =  **Beware of circular arguments which avoid doing part (a) e.g.**  Integration is used on the given derivative to give *y* in terms of *x*, *k* and *c*  (3, −10) is substituted to give 3*k* + *c* = 8  Part (b) is then done first using *k* = 12 to find *c* = −28  This is then substituted into 3*k* + *c* = 8 to give *k* = 12  This scores (a) M0A0 (b) M1dM1A1 (if −28 is identified as the intercept) | | | |

**Alternative for part (a) using algebraic division:**



leading to  and then .

**M1:** Attempts to divide the given cubic by  and proceeds as far as a remainder set = 0. Requires at least .

**A1\*:** Obtains  with no errors seen and sufficient working. Their algebraic division needs to be correct but allow them to have either  or 0 as their “remainder”. If their remainder is given in their working as 0 they may proceed directly to .

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **6(a)** | and | **M1** | 1.1b |
| therefore *AD* is parallel to *BC \** | **A1\*cso** | 2.2a |
|  | **(2)** |  |
| **(b)** | Attempt to find at least two lengths between *AB*, *BC*, *CD* and *AD*    (awrt 115 m) | **M1** | 1.1b |
| **A1** | 1.1b |
| Average speed | **dM1** | 3.1b |
| awrt  (km/h) | **A1** | 3.2a |
|  | **(4)** |  |
| **(6 marks)** | | | |
| **Notes** | | | |
| **(a)**  **M1:** Attempts to find both  and .  May be seen as column vectors.  Condone poor notation with column vectors e.g.  or  for  This mark can be scored for at least one correct component for each vector if no method is shown.  May be implied if they go straight for ratios (gradients) e.g. ,  Some candidates use distances in an attempt to prove part (a) e.g. finding  and  in  which case the M1 can be implied. Adding vectors scores M0  **A1\*cso:** This mark requires   * correct work showing *AD* is parallel to *BC* by showing that e.g.  or equivalent e.g.  or e.g.  or e.g. (i.e. the vector arrows are not required) or by showing the ratio/gradient of the lines through *AD* and *BC* are equal   e.g. . Condone e.g.   * a (minimal) conclusion e.g. ✓, hence shown, etc. which may be in a preamble e.g. if they are parallel then *AD* = *kBC*…etc. If using ratios/gradients they need to say that they are parallel. * vectors correctly calculated but allow e.g.  and allow poor column vector notation as above   Using reciprocal gradients for both is acceptable for A1 even if they call them “gradients”.  Do not credit work in part (b) in part (a) unless used in part (a)  **(b)**  **M1:** Attempts to use Pythagoras to find **at least two** of the lengths of the quadrilateral.  May be implied by at least 2 correct lengths.  For reference  Allow ft if using their vectors from part (a) provided subtraction was used. Do not be concerned about  the signs of individual components but must be using subtraction (but condone ) to  find the vectors and then squaring and adding components and then taking the square root.  **A1:** At least 2 lengths correct: If units are given they must be correct.  (allow awrt 115 m)    Allow if they are working in km e.g.  etc.  M1A1 is implied by a total distance of awrt 291 (m) or possibly a multiple of this if they are doubling  (awrt 583) or e.g. multiplying by 24 (awrt 6990) etc.  **dM1:** For an attempt at an average speed ignoring any attempt to get the correct units.  They must have attempted all 4 lengths for this mark.  There must be some indication that they have divided by 5 but this may be implied.  Allow this mark if they calculate the average speed for 2 laps or 1 lap e.g.  or e.g. if they divide by 2.5 or multiply by 24.  **A1:** awrt 6.99 (km/h). or anything which truncates to 6.99 e.g. 6.995. Units are **not** required but if they are  given they must be correct. Isw once a correct answer is seen.  **An exact answer is acceptable for the final A1 in (b):** | | | |

**Special Case:**

Some candidates are misinterpreting/misreading the position vector for *B* as 16**i** rather than16**j**

This is usually implied by their vectors/ratios e.g.

 and 

or e.g.



For part (a), the maximum possible score is **M1A0** with the conditions for the M mark as described in the main scheme.

For part (b) the maximum possible score is **M1A1M1A0** as follows:

**M1:** Attempts to use Pythagoras to find **at least two** of the lengths of the quadrilateral as defined in the main scheme.

For reference 

**A1:** Correct lengths for *AD* and *CD*. If units are given they must be correct.

This may **not** be scored for correct ft lengths for *AB* or *BC*

So requires both:

(allow awrt 115 m)



**dM1:** As abovefor an attempt at an average speed ignoring any attempt to get the correct units.

**A0:** Not available

If the position vector for *B* is not misinterpreted/misread in part (b) then full marks are available.

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| --- | --- | --- | --- |
| **Question** | **Scheme** | **Marks** | **AOs** |
| **7(a)** |  | **M1** | 1.1b |
|  | **B1** | 1.1b |
|  | **M1** | 2.1 |
|  | **A1** | 1.1b |
|  | **(4)** |  |
| **(b)** | or e.g. | **M1** | 1.1b |
|  | **dM1** | 1.1b |
|  | **A1** | 2.2a |
|  |  | **(3)** |  |
| **(7 marks)** | | | |
| **Notes** | | | |
| **(a)** Allow equivalent notation for the  e.g.  **M1:** Attempts to differentiate  **and**  where … are constants  **B1:** Correct application of the product rule on 2*xy*:  Note that some candidates have a spurious at the start (as their intention to differentiate) and this  can be ignored for the first 2 marks  **M1:** For a valid attempt to make  the subject, with exactly 2 different terms in  coming from  and  2*xy*. Look for  which may be implied by their working.  Condone slips provided the intention is clear.  For those candidates who had a spurious at the start, they may incorporate this in their  rearrangement in which case they will have 3 terms in and so score M0.  If they ignore it, then this mark is available for the condition as described above.  **A1:**  oe e.g.  Isw once a correct expression is seen.  Note that it is sometimes unclear if the minus sign(s) is/are correctly placed and you may have to use  your judgement. Evidence may be available in part (b) to help you decide if they have the correct  expression.  **(b)**  **M1:** Substitutes *x* = ˗2 and *y* = 5 into  They must have *x*’s and *y*’s in their  but condone slips in substitution provided the intention is clear.  As a minimum look for at least one *x* and at least one *y* substituted correctly.  Note that this mark may be implied by their value for  and may be implied if, for example, they find  the negative reciprocal or the reciprocal of  and then substitute *x* = ˗2 and *y* = 5  Alternatively, substitutes *x* = ˗2 and *y* = 5 into their attempt to differentiate and then rearranges to find a value or numerical expression for  **dM1:** Attempts to find the equation of the normal using their gradient of the tangent and *x* = ˗2 and *y* = 5  correctly placed. Score for an expression of the form  or if they use  they must proceed as far as *c* =… Must be using the **negative reciprocal** of the tangent gradient.  Note that  is not a correct method unless the gradient is evaluated first *before*  expanding.  **A1:**  or any integer multiple of this equation including the “= 0”, not just *a*, *b*, *c* given.  e.g., is likely if they don’t cancel down their gradient. | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **8(a)** |  | **B1** | 1.1b |
|  | **M1** | 1.1b |
|  | **A1** | 2.2a |
|  | **(3)** |  |
| **(b)(i)** |  | **M1** | 1.1b |
|  | **A1** | 2.2a |
| **(ii)** | awrt 1.33 | **B1ft** | 2.2a |
|  | **(3)** |  |
| **(6 marks)** | | | |
| **Notes** | | | |
| **(a)**  **B1:** *R* =  or  or  score B0  (Condone if this comes from e.g., )  Decimal answers score B0 unless the exact value is seen then apply isw.  **M1:** Proceeds to a value for *α* from  May be implied by awrt 1.33 radians or 76 degrees  **A1:** awrt 1.326 for *α*. Apply isw if this is then subsequently rounded to e.g. 1.33 | | | |
| **(b)(i)**  **M1:** For a value of  or allow ± 4.5*R* (with the letter *R*)  But not embedded in an expression e.g. unless extracted later.  Note that the sum may be found as  with the maximum then found using calculus  e.g.  This will score M1 once they reach  May be implied by or awrt 37.1 (which may come from a graphical method)  May also see e.g.  **A1:**  or exact equivalent e.g.  and apply isw once a correct answer is  seen  **(ii)**  **B1ft:** awrt 1.33 (or follow through on their *α* even if in degrees (76), no matter how accurate) | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **9(a)**  **Way 1** |  | **M1** | 1.1b |
|  | **M1** | 2.1 |
|  | **A1cso** | 1.1b |
|  | **(3)** |  |
|  | **(a) Way 2** |  |  |
|  | **M1** | 1.1b |
|  | **M1** | 2.1 |
|  | **A1cso** | 1.1b |
|  | **(a) Way 3** |  |  |
|  | **M1** | 1.1b |
| or | **M1** | 2.1 |
|  | **A1cso** | 1.1b |
|  | **(a) Way 4** |  |  |
|  | **M1** | 1.1b |
|  | **M1** | 2.1 |
| e.g. | **A1cso** | 1.1b |
| **(b)** | oe e.g. | **B1ft** | 2.2a |
| **or** | **M1** | 2.1 |
|  | **dM1** | 3.1a |
|  | **A1** | 2.2a |
|  | **(4)** |  |
| **(7 marks)** | | | |
| **Notes** | | | |
| **Choose the mark scheme that best matches their chosen method.**  **(a) Way 1**  **M1:** Attempts to complete the square. Award for sight of  where … ≠ 0  **M1:** Rearranges their  to either  or  and then substitutes correctly their expression into the parametric equation for *y*. So e.g.,  is M0.  **A1cso:**  including brackets with all stages of working shown.  The “*y* =” must appear at some point.  **Way 2**  **M1:** Attempts to use the power rule for logarithms  where … ≠ 6  **M1:** Writes  as  and then multiplies out and substitutes correctly in for *t* to obtain a  Cartesian equation for *C*  **A1cso:**  including brackets with all stages of working shown.  The “*y* =” must appear at some point.  **Way 3**  **M1:** Attempts to make *t* the subject for  to obtain  where … ≠ 0  **M1:** Substitutes  correctly into  and rearranges to make *y* the subject.  **A1cso:**  including brackets with all stages of working shown.  The “*y* =” must appear at some point.  **Way 4**  **M1:** Attempts to complete the square. Award for sight of  where … ≠ 0  **M1:** Attempts to find  where  and uses the completed square form to find  in  terms of *x* and then integrates to obtain a Cartesian equation for *C*  **A1cso:** A complete method using any correct point on the curve to show that *c* = 0 and obtain  with all stages of working shown. The “*y* =” must appear at some point.  **Note that a common incorrect approach in (a) is:**    **which scores no marks.** | | | |
| **(b)**  **B1ft:** Deduces oe e.g  but allow follow through on their Cartesian equation with *x* = 0  and apply isw after a correct value or ft value for *y*  **M1:** Attempts to find  when  so score for obtaining  and substituting in  Allow this mark if they use the letters *A* and *B* e.g.  or allow a “made up” *A* and *B*.  **or**  Attempts to find  when  by finding  For the derivative look for  **NOTE** ifcandidates find  we will give BOD that *t* = 2 has been used unless  there is clear evidence that *t* = 2 has not been used.  **dM1:** Attempts to find the equation of the tangent. Score for sight of  or if they use  they must proceed as far as *c* = … **It is dependent on the previous method mark.**  Must have numeric *A* and *B* now.  **A1:**  or any integer multiple of this equation in the form | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **10(a)** | e.g.  **or** | **B1** | 1.1b |
| or  **or**    or | **M1** | 1.1b |
|  | **A1** | 1.1b |
|  | **(3)** |  |
| **(b)** |  | **M1** | 1.2 |
|  | **A1ft** | 1.1b |
|  | **dM1** | 3.1a |
|  | **A1** | 2.2a |
|  | **(4)** |  |
| **(7 marks)** | | | |
| **Notes** | | | |
| **(a)**  **B1:** Correct form for the partial fractions and sets up the correct corresponding identity which may be  implied by two equations in *A* and *B* if they are comparing coefficients.  **M1:** Either   * substitutes  or  in an attempt to find *A* or *B* in terms of *k* * expands the rhs, collects terms and compares coefficients in an attempt to find *A* or *B* in terms of *k*   **Or** may be implied by one correct fraction (numerator **and** denominator)  You may see candidates substituting two other values of *x* and then solving simultaneous equations.  **A1:** Achieves  with no errors. Must be the correct partial fractions not just for correct  numerators. May be seen in (b). Correct answer implies B1M1A1. One correct fraction only B0M1A0 | | | |
| **(b)**  **M1:** Attempts to find. Score for either  or  Allow the … to be in terms of *k* or just constants but there must be no *x* terms.  Condone invisible brackets for this mark.  **A1ft:**  but condone round brackets e.g.  or equivalent e.g.    Follow through their partial fractions with numerators which must both be in terms of *k*.  Condone missing brackets as long as they are recovered later e.g. when applying limits.  **dM1:** A full attempt to find the value of *k.* To score this mark they must have attempted to integrate their  partial fractions, substituted in the correct limits, subtracted either way round, set = 21 and  attempted to solve to find *k*. Condone omission of the terms containing ln(1) or ln(˗1).  Note that e.g. ln(˗5) or ln(5) must be seen but may be disregarded **after** substitution and subtraction.  Do not be concerned with the processing as long as they proceed to *k* = …  Condone if they use *x* instead of *k* after limits have been used as long as the intention is clear.  **A1:** Deduces  or exact equivalent e.g..  Allow recovery from expressions that contain e.g. ln(−5) as long as it is dealt with subsequently.  Also allow recovery from invisible brackets. Condone  **Some candidates may use substitution in part (b) e.g.**        Score **M1** for integrating at least once to an appropriate form as in the main scheme e.g. …ln*u*  **A1ft:** For  but condone  which may be seen separately  Follow through their “*A*” and “*B*” in terms of *k*.  Condone missing brackets as long as they are recovered later e.g. when applying limits.  **dM1:** A full attempt to find the value of *k.* To score this mark they must have attempted to integrate their  partial fractions using substitution, substituted in the correct changed limits and subtracts either way  round, set = 21 and attempted to solve to find *k*. Do not be concerned with processing as long as they  proceed to *k* = … Condone omission of terms which contain e.g. ln(1) or ln(˗1).  Note that e.g. ln(˗5) or ln(5) must be seen but may be disregarded **after** substitution and subtraction.      **A1:**  or exact equivalent e.g. .  Allow recovery from expressions that contain e.g. ln(−5) as long as it is dealt with subsequently.  Also allow recovery from invisible brackets. | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **11(a)** | oe e.g. | **B1** | 1.1b |
|  | **M1** | 3.1a |
| \* | **A1\*** | 2.1 |
|  | **(3)** |  |
| **(b)** |  | **M1** | 1.1b |
| oe e.g. | **A1** | 1.1b |
|  | **dM1** | 3.4 |
|  | **ddM1** | 3.1b |
| oe e.g. | **A1** | 3.3 |
|  |  | **(5)** |  |
|  | **(b) Alternative:** |  |  |
|  |  | **M1** | 1.1b |
| oe | **A1** | 1.1b |
| **and**  **or** | **dM1** | 3.4 |
| **and** | **ddM1** | 3.1b |
| oe e.g. | **A1** | 3.3 |
|  | **(5)** |  |
| **(c)** |  | **M1** | 3.4 |
|  | **A1** | 3.2a |
|  | **(2)** |  |
| **(10 marks)** | | | |
| **Notes** | | | |
| **(a)**  **B1:** For stated or used – may be implied by their chain rule attempt  **M1:** Requires:    * or e.g.  (or a suitable letter for *k*, which may be *λ*, but must **not** be a number) * **application** of the correct chain rule  or any equivalent with  or and their correctly placed. So  scores M0 as  is incorrectly placed.   **A1\*:** A rigorous argument with all steps shown and simplifies to achieve  with no errors.  Do not allow the use of for both constants. Allow use of e.g.  for full marks.  e.g.  scores B1M1A0\* *unless* e.g. “let ” seen.  Allow correct work leading to e.g.  or  so  There must be an attempt to link the  with the  which may be missing an = sign.  Allow an argument with  e.g.  Withhold this A mark if there are notational errors e.g.  scores B1(implied)M1A0\* | | | |
| **(b) Note that some candidates may work with e.g.**  or e.g. **which is acceptable.**  **Candidates who do not have a *λ*  e.g. assume**  or e.g.  **then only the first 2 method marks are available (see note below). Condone use of other variables if the intention is clear but the final answer must be in terms of *h* and *t*.**  **M1:** Separates the variables and integrates to obtain an equation of the form  oe  The constant of integration is not needed for this mark.  **A1:**  oe. The constant of integration is not needed for this mark.  Condone spurious notation for this intermediate mark e.g. integral signs left in after integrating.  **dM1:** Substitutes  and  and attempts to find *c*.  **It is dependent on the previous method mark.**  Do not be concerned with the “processing” to find “*c*” as long as they are using  and  May be implied by their value of *c*.  **ddM1:** Substitutes  and  and their *c* and attempts to find . Do not be concerned with the  “processing” to find as long as they are using  and .  **It is dependent on both previous method marks.**  **A1:** Correct equation in the correct form from correct work.  or  Must follow A1 earlier so do check if this has been obtained fortuitously. Allow 1.73 for 1.728    Note candidates who do not have a *λ*  e.g. assume or e.g.  can use either  and  **or**  and  to find their constant of integration.  **(b)Alternative:**  **M1:** Finds the reciprocal of both sides and integrates to obtain an equation of the form  **A1:**  oe. The constant of integration is not needed for this mark.  **dM1:** Substitutes  and  **and** substitutes  and  **and** attempts to find *λ* **or** *c*.  **It is dependent on the previous method mark.**  Do not be concerned with the “processing” to find *λ* or *c* as long as they are using  and  and  and  and reach a value for *λ* or *c*. May be implied by their value(s).  **ddM1:** Complete attempt to find *λ* **and** *c*.  **It is dependent on both previous method marks.**  Do not be concerned with the “processing” to find and *c* as long as they are using  and  and  and .  **A1:** Correct equation in the correct form.  or  Must follow A1 earlier so do check if this has been obtained fortuitously. Allow 1.73 for 1.728  **Special Case:**  Some candidates are using the given equation in part (b) to find the value of *A* and the value of *B* using the given conditions. May score a maximum of 00110. This should be marked as follows:  **M0A0**: (No attempt to integrate)  **M1:** Substitutes *t* = 0 and *h* = 1.44 to find a value for *B*  **dM1:** Substitutes *t* = 8 and *h* = 3.24 with their value of *B* to find a value for *A*  **A0:** Since they have not used the given model.  (Allow full recovery in (c) if this equation is correct) | | | |
| **(c)**  **M1:** Attempts to substitute *h* = 5 into their equation which must be of the form  or possibly a  rearranged equation e.g.  with values of *A* and *B* leading to a value for *t*.  Do not be concerned about the processing as long as they use *h* = 5 and obtain a value for *t* even if *t* is  negative.  **A1:** Awrt 18.4 minutes **following a correct equation** **in (b)**.  The units are required but allow e.g. min, mins, but not just 18.4 and not m (which means metres)  Allow e.g. 18 minutes 25 seconds or 18 mins 26 secs  Note this may follow A0 in part (b) as they may have rearranged incorrectly in (b) but use a correct  equation in (c) e.g.  or may come from the special case.  Apply isw following a correct time and units, e.g., 18.4 followed by 18 mins. | | | |

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **12(a)** |  | **M1** | 3.4 |
| 5000 (subscribers) | **A1** | 3.2a |
|  | **(2)** |  |
| **(b)** |  | **B1** | 3.4 |
| This was the point when company A had the lowest number of subscribers | **B1** | 2.4 |
|  | **(2)** |  |
| **(c)** |  |  |  |
| o.e. or  o.e. | **B1** | 3.1a |
| or | **M1** | 3.4 |
| One of the two critical values | **A1** | 1.1b |
| Chooses the outside region for their **two** values of *t*  Both of , | **A1ft** | 2.2a |
|  | **A1** | 2.5 |
|  | **(5)** |  |
| **(d)** | The number of subscribers will become negative (when ) | **B1** | 3.5b |
|  | **(1)** |  |
| **(10 marks)** | | | |
| **Notes** | | | |
| **(a)**  **M1:** Uses the models to find the difference when . Allow slips in evaluating *N*A and *N*B but it  must be clear that *t* = 0 is being used. Just 5 with no working implies M1.  **A1:** 5000 or 5 thousand (subscribers) (5 is A0) | | | |
| **(b)**  **B1:**  Just look for the number 3 so e.g. *t* > 3 or e.g. “just after 3” is acceptable.  If more than one value is offered then score B0 unless it is clear that the 3 is intended.  Must be seen in (b) not just on their diagram.  **B1:** Any acceptable reason e.g.   * This was the point when company A had the lowest number of subscribers * After this point the number of subscribers started to increase * It is the minimum * Condone “it is the turning point” * The graph changes direction * It is the vertex * The gradient becomes positive * NA increased   Allow this mark even if the first B mark was not scored e.g. *T* = 3.5 because the graph starts to increase scores B0B1  Do not allow contradictory statements.  Do not allow:   * The graph reflects at *t* = 3 on its own without further clarification | | | |
| **(c)**  **B1:** Forms one valid equation (allow an equation or any inequality sign)  **M1:** Attempts to solve one valid equation (allow an equation or any inequality sign)  **A1:** For either  only (allow an equation or any inequality sign) or exact equivalent  Must be seen or used in part (c).  **See notes below for attempts that use “squaring” to find the values of *t*.**  **A1ft:** Chooses the outside region for their **two** values of *t* where *t* > 0.  So for *t* = *a* and *t* = *b* where 0 < *a < b* should be *t* < *a* , *t* > *b*. Allow , /or/and//  Condone if incorrectly combined e.g.  but **not**  **A1:** Fully correct solution in the form or  or  either way around but condone  , ,  or .  It is not necessary to mention , e.g.  Look for  and  or condone  Do not allow solutions not in set notation such as .  Note that a lower bound for  and an upper bound for are not required but may be  included e.g. or  Note that the marks in this part require **valid** equations to be solved. They must have removed the mod brackets and arrived at an equation equivalent to  or  (all you need to check initially is whether their equation **without mod brackets** is equivalent to one of these).  Note that  is condoned for the A1ft but not for the final A1.  If *x* is used in their set notation then final A0, but we would condone this for the penultimate A1ft.  **See notes below for answers given with no working.** | | | |
| **(d)**  **B1:** Requires any indication that the number of subscribers will become negative. E.g.   * It allows negative subscribers (which isn’t possible) * so not valid after *t* = 7 but condone not valid for *t* after (any value above 7)   But not   * Subscribers will become zero | | | |

**Guidance for attempts that use “squaring” to find the values of *t* in (c):**

**Way 1:**

|  |  |  |
| --- | --- | --- |
| o.e. or  o.e. | **B1** | 3.1a |
| o.e. (Gives −9 and )  or  o.e. (Gives 15 and ) | **M1** | 3.4 |
| One of the two critical values | **A1** | 1.1b |
| Chooses the outside region for their **two** values of *t*  Both of , | **A1ft** | 2.2a |
|  | **A1** | 2.5 |

**Way 2:**

|  |  |  |
| --- | --- | --- |
| o.e. | **B1** | 3.1a |
| (Gives  and ) | **M1** | 3.4 |
| One of the two critical values | **A1** | 1.1b |
| Chooses the outside region for their **two** values of *t*  Both of , | **A1ft** | 2.2a |
|  | **A1** | 2.5 |

**B1:** Forms one valid equation and squares both sides (allow an equation or any inequality sign)

May be implied by e.g. 

Alternatively, arrives at  (o.e.) as in way 2.

**M1:** Attempts to solve one valid equation after squaring both sides (allow an equation or any

inequality sign). Note that it is acceptable to just solve 

**A1:** As in main scheme. **A1ft:** As in main scheme. **A1:** As in main scheme.

Note: the following is common and scores 00000.



Which typically leads to



**Guidance for answers only in part (c):**

 where … is any inequality or equation scores **11000**

 where … is any inequality or equation scores **11100** for one correct c.v.

**Both**  where  scores **11010** for outside region.

**Both**  where scores **11010** for outside region.

**Both**  where  scores **11110** for outside region with one correct.

**Both**  where  scores **11110** for outside region with one correct.

**Both**  scores **11110** for outside region with one correct.

Fully correct e.g.  scores **11111**

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| **Question** | **Scheme** | **Marks** | **AOs** |
| **13(a)** |  | **M1** | 1.1b |
|  | **M1** | 1.1b |
|  | **A1** | 1.1b |
|  | **A1** | 2.1 |
|  | **(4)** |  |
| **(a)**  **M1:** Attempts a binomial expansion by taking out a factor of  and achieves at least the first 3  terms in their expansion. May be seen separately e.g.  and  **M1:** A correct method to find either the *x* or the  term unsimplified.  Award for  where *k* ≠ 1. Condone invisible brackets.  **A1:** For a correct unsimplified or simplified expansion of e.g.  or  Do not condone missing brackets unless they are implied by subsequent work.  Condone for  **Also allow this mark for 2 correct simplified terms from** **with both method marks scored.**  **A1:**  cao Allow terms to be listed. Ignore any extra terms. Isw once a correct **simplified** answer  is seen.  **Direct expansion, if seen, should be marked as follows:**    **M1:** For  **M1:** A correct method to find either the *x* or the  term unsimplified.  Award for . Condone invisible brackets.  **A1:** For a correct unsimplified or simplified expansion of e.g.  **Also award for at least 2 correct simplified terms from**  **with both method marks scored.**  **A1:**  cao Allow terms to be listed. Ignore any extra terms. Isw once a correct **simplified**  answer is seen.  **Note that M0M1A1A0 is a possible mark trait in either method** | | | |

**Note regarding a possible misread in parts (b) and (c)**

Some candidates are misreading  in parts (b) and (c) as 

**If parts (b) and (c) are consistently attempted** with then we will allow theM marks in (b) **only**. **M1** for  applied to their expansion in part (a) or 6 (their expansion in part (a)) and **dM1** for substituting in 0.4 and 0.2 and subtracting either way round (may be implied).

**No marks are available in part (c)**

**MARK PARTS (b) and (c) TOGETHER**

|  |  |  |  |
| --- | --- | --- | --- |
| **(b)** |  | **M1** | 1.1b |
| oe | **A1** | 1.1b |
|  | **dM1** | 3.1a |
| or | **A1** | 1.1b |
|  | **(4)** |  |
|  |  |  |
| **(b)**  **M1:** Attempts to multiply their expansion from part (a) by 6*x* or just *x* and attempts to integrate. Condone  copying slips and slips in expanding. Look for  at least once having multiplied by 6*x* or *x*.  Ignore e.g. spurious integral signs.  **A1:** Correct integration, simplified or unsimplified.  oe e.g.  If they have extra terms they can be ignored.  Ignore e.g. spurious integral signs.  **dM1:** An overall problem-solving mark for   * using part (a) by integrating  their binomial expansion and * substituting in 0.4 and 0.2 and subtracting either way round (may be implied)   For evidence of using the correct limits we do not expect examiners to check so allow this mark if they obtain a value with (minimal) evidence of the use of the limits 0.4 and 0.2.  This could be e.g.  provided the first M was scored. If the integration was correct, evidence can be taken from answer of awrt 0.0330 if limits are not seen elsewhere. **Depends on the first M mark.**  **A1:** awrt 0.03304 (NB allow the exact value which is ).  Isw following a correct answer.  Note answers which use additional terms in the expansion to give a different approximation score A0  Also note that the actual value is 0.032865… | | | |

**Some may use integration by parts in (b) and the following scheme should be applied.**

**Integration by parts in (b):**

**Either by taking**  and 





**M1:** A full attempt at integration by parts. This requires:



Where f(*x*) is an attempt to integrate their expansion from (a) with  at least once

**and** g(*x*) is an attempt to integrate their f(*x*) with  at least once

**A1:** Fully correct integration. Then **dM1A1** as in the main scheme

**Or by taking**   and 





**M1:** A full attempt at integration by parts. This requires:



Where f(*x*) is their expansion from (a) and g(*x*) is an attempt to differentiate their f(*x*) with  at least once **and** h(*x*) is an attempt to integrate their  with  at least once

**A1:** Fully correct integration. Then **dM1A1** as in the main scheme

|  |  |  |  |
| --- | --- | --- | --- |
| **(c)** | Overall problem-solving mark (see notes) | **M1** | 3.1a |
|  | **M1** | 1.1b |
|  | **A1** | 1.1b |
|  | **ddM1** | 1.1b |
| oe | **A1** | 2.1 |
|  | **(5)** |  |
| **(c)**  **Alt 1** | Overall problem-solving mark (see notes) | **M1** | 3.1a |
| oe | **M1** | 1.1b |
| oe | **A1** | 1.1b |
|  | **ddM1** | 1.1b |
| oe | **A1** | 2.1 |

|  |  |  |  |
| --- | --- | --- | --- |
| **(c)**  **Alt 2** | Overall problem-solving mark (see notes) | **M1** | 3.1a |
| oe | **M1** | 1.1b |
| oe | **A1** | 1.1b |
|  | **ddM1** | 1.1b |
| oe | **A1** | 2.1 |
| **(13 marks)** | | | |
| **Notes** | | | |
| **(c) There are various methods which can be used**  **M1:** An overall problem-solving mark for **all of**   * using an appropriate integration technique e.g. substitution, by parts or partial fractions – note that this may not be correct but mark positively if they have tried one of these approaches * integrates one of their terms to a natural logarithm, e.g.,  or * substitutes in correct limits and subtracts either way round   **M1:** Integrates to achieve an expression of the required form for their chosen method   * substitution:  or e.g. * parts:  condone missing brackets e.g.  for * partial fractions:  condone missing brackets e.g.  for   **A1:** Correct integration for their method e.g.   * substitution: or e.g. * parts: * partial fractions: oe e.g.   Note that the above terms may appear “separated” but must be correct with the correct signs.  (ignore any reference to a constant of integration)  Do not condone missing brackets e.g.  for unless they are implied by later work.  **ddM1:** Substitutes in the correct limits for their integral and subtracts either way round to find a value  **Depends on both previous method marks.**  For evidence of using the correct limits we do not expect examiners to check so allow this mark if  they obtain a value with (minimal) evidence of the use of the appropriate limits.  This could be e.g.  provided both previous M marks were scored.  Note that for substitution they may revert back to 3 + *x* and so should be using 0.4 and 0.2  **A1:** A full and rigorous argument leading to  or exact equivalent e.g.  or  e.g.  The brackets are not required around the and allow exact equivalents e.g. allow 1.0625 or  but not e.g. . The  must be exact or an exact equivalent. Also allow e.g.  Ignore spurious integral signs that may appear as part of their solution. | | | |

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| --- | --- | --- | --- |
| **Question** | **Scheme** | **Marks** | **AOs** |
| **14(a)** | e.g. | **B1** | 1.2 |
|  | **M1A1** | 2.1  2.2a |
|  | **(3)** |  |
| **(b)** |  |  |  |
|  | **B1** | 2.2a |
|  | **M1** | 1.1b |
|  | **dM1** | 1.1b |
| only | **A1** | 2.3 |
|  | **(4)** |  |
| **(7 marks)** | | | |
| **Notes** | | | |
| **(a) Allow use of e.g. *x* but the final mark requires the equation to be in terms of *θ***  **B1(M1 on EPEN):** For recalling and using at least one correct trigonometric identity in the given equation.  e.g. one of:  This may be seen explicitly or may be implied by their working by e.g.  or they might  multiply both sides by  leaving  on the rhs implying  **M1:** For manipulating the equation using trigonometric identities (condoning sign slips only in the  identities and arithmetic slips) to obtain an expression of the form:  or  with *A*, *B*, *C* ≠ 0  **A1:**  oe e.g.  cao  Note that this is not a given answer so condone notational slips e.g. for  provided the intention is clear but the final equation must have no notational errors.  Note that the “= 0” is not required for the M1 but is required for the A1  **Note: some candidates arrive at the correct final answer fortuitously following errors in their work.** | | | |

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| --- |
| **(b) Allow all marks in (b) to score if the correct equation is obtained fortuitously in part (a)**  **Also allow use of *θ* instead of *x* throughout in part (b). Correct answers, no working scores max 1000**  **B1:** For one of  Condone *x* = 2*π* or *x* = 3*π* for this mark.  The degrees symbol is not required. This may come from cos *x* = 1  **M1:** Attempts to solve their 3TQ from part (a) or a “made up” 3TQ (which may only be seen in (b)) leading  to a value for cos *x*. The general guidance for solving a 3 term quadratic equation can be applied.  Allow solution(s) from a calculator which may be implied by at least one correct value for their 3TQ.  Must be a value for cos *x* and not e.g. *x*.  **dM1:** Attempts to find one of their angles in the range  (but not 450) for their cos *x* = *k* where  May be implied by their value(s) but must be in degrees.  Requires them to state a value for cos*x*. Must be checked (you can check cos(their *x*) = their *k* (1sf))  **A1:** only with no other values in range (including 450).  The degrees symbol is not required. awrt 491 must come from |

|  |  |  |  |
| --- | --- | --- | --- |
| **Question** | **Scheme** | **Marks** | **AOs** |
| **15** | o.e. | **M1** | 1.1b |
| Examples: | **A1** | 2.2a |
| As *x* is obtuse then  is positive because  and so we have a contradiction.  Therefore  \* | **A1\*** | 2.4 |
| **(3 marks)** | | | |
| **Notes** | | | |
| **Condone poor notation e.g.  or e.g.  for the first two marks only.**  **M1:** Expands to obtain  where *k* = 1 or 2 o.e. May be implied.  **A1:** Uses a correct identity  or e.g.  to obtain a correct inequality in  any form that does not include the and  terms. Condone e.g.  **A1\*:** Fully correct work which includes   * a convincing argument that explains why their inequality is not true * a statement that indicates there is a contradiction * a conclusion that  (there is no need to repeat “when *x* is obtuse”) * no contradictory statements * no mixed/missed variables, e.g.,   **Examples:**  From :  -------------------------------------  In the second quadrantis  “(this is a) contradiction” or equivalent (therefore)  or  As *x* is obtuse, sin *x* > 0, cos *x* < 0 so  “(this is a) contradiction” or equivalent (therefore)  From :  ------------------------------  As *x* is obtuse, 2*x* is reflex o.e. (i.e. π < 2*x* < 2π) so  “(this is) wrong” or equivalent (therefore)  From :  --------------------------  As *x* is obtuse, 2*x* is reflex o.e. (i.e. 180 < 2*x* < 360) so  so  “(this is a) contradiction” or equivalent (therefore)  From :  ------------------------------  As *x* is obtuse, 2*x* is reflex o.e. (i.e. 180 < 2*x* < 360) so  “(this is) incorrect” or equivalent (therefore)  **Note** that you may condone the absence of a statement referring to the fact that  is only valid since when *x* is obtuse. | | | |

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