

MARK SCHEME for the October/November 2012 series

9709 MATHEMATICS

9709/31

Paper 3, maximum raw mark 75

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Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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Mark Scheme Notes

Marks are of the following three types:

M Method mark, awarded for a valid method applied to the problem. Method marks are not lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.

A Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated method mark is earned (or implied).

B Mark for a correct result or statement independent of method marks.

- When a part of a question has two or more “method” steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly when there are several B marks allocated. The notation DM or DB (or dep*) is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.
- The symbol $\checkmark$ implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only. A and B marks are not given for fortuitously “correct” answers or results obtained from incorrect working.
- Note: B2 or A2 means that the candidate can earn 2 or 0.
B2/1/0 means that the candidate can earn anything from 0 to 2.

The marks indicated in the scheme may not be subdivided. If there is genuine doubt whether a candidate has earned a mark, allow the candidate the benefit of the doubt. Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored.

- Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise.
- For a numerical answer, allow the A or B mark if a value is obtained which is correct to 3 s.f., or which would be correct to 3 s.f. if rounded (1 d.p. in the case of an angle). As stated above, an A or B mark is not given if a correct numerical answer arises fortuitously from incorrect working. For Mechanics questions, allow A or B marks for correct answers which arise from taking g equal to 9.8 or 9.81 instead of 10.

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The following abbreviations may be used in a mark scheme or used on the scripts:

AEF	Any Equivalent Form (of answer is equally acceptable)
AG	Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)
BOD	Benefit of Doubt (allowed when the validity of a solution may not be absolutely clear)
CAO	Correct Answer Only (emphasising that no “follow through” from a previous error is allowed)
CWO	Correct Working Only – often written by a ‘fortuitous’ answer
ISW	Ignore Subsequent Working
MR	Misread
PA	Premature Approximation (resulting in basically correct work that is insufficiently accurate)
SOS	See Other Solution (the candidate makes a better attempt at the same question)
SR	Special Ruling (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)

Penalties

MR –1	A penalty of MR –1 is deducted from A or B marks when the data of a question or part question are genuinely misread and the object and difficulty of the question remain unaltered. In this case all A and B marks then become “follow through $\sqrt{}$ ” marks. MR is not applied when the candidate misreads his own figures – this is regarded as an error in accuracy. An MR –2 penalty may be applied in particular cases if agreed at the coordination meeting.
PA –1	This is deducted from A or B marks in the case of premature approximation. The PA –1 penalty is usually discussed at the meeting.

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- 1 *EITHER* State or imply non-modular inequality $(3(x-1))^2 < (2x+1)^2$
or corresponding quadratic equation, or pair of linear equations $3(x-1) = \pm (2x+1)$ B1
Make reasonable solution attempt at a 3-term quadratic, or solve two linear equations M1
Obtain critical values $x = \frac{2}{5}$ and $x = 4$ A1
State answer $\frac{2}{5} < x < 4$ A1
- OR* Obtain critical value $x = \frac{2}{5}$ or $x = 4$ from a graphical method, or by inspection, or by solving a linear equation or inequality B1
Obtain critical values $x = \frac{2}{5}$ and $x = 4$ B2
State answer $\frac{2}{5} < x < 4$ B1 [4]
[Do not condone $\leq$ for $<$.]
- 2 *EITHER* Use laws of indices correctly and solve for 5^x or for 5^{-x} or for 5^{x-1} M1
Obtain 5^x or for 5^{-x} or for 5^{x-1} in any correct form, e.g. $5^x = \frac{5}{1-1/5}$ A1
Use correct method for solving $5^x = a$, or $5^{-x} = a$, or $5^{x-1} = a$, where $a > 0$ M1
Obtain answer $x = 1.14$ A1
- OR* Use an appropriate iterative formula, e.g. $x_{n+1} = \frac{\ln(5^{x-1}+5)}{\ln 5}$, correctly, at least once M1
Obtain answer 1.14 A1
Show sufficient iterations to at least 3 d.p. to justify 1.14 to 2 d.p., or show there is a sign change in the interval (1.135, 1.145) A1
Show there is no other root A1 [4]
[For the solution $x = 1.14$ with no relevant working give B1, and a further B1 if 1.14 is shown to be the only solution.]
- 3 Attempt use of $\sin(A+B)$ and $\cos(A-B)$ formulate to obtain an equation in $\cos \theta$ and $\sin \theta$ M1
Obtain a correct equation in any form A1
Use trig. formula to obtain an equation in $\tan \theta$ (or $\cos \theta$, $\sin \theta$ or $\cot \theta$) M1
Obtain $\tan \theta = \frac{\sqrt{6}-1}{1-\sqrt{2}}$, or equivalent (or find $\cos \theta$, $\sin \theta$ or $\cot \theta$) A1
Obtain answer $\theta = 105.9^\circ$, and no others in the given interval A1 [5]
[Ignore answers outside the given material]
- 4 (i) Obtain correct unsimplified terms in x and x^3 B1 + B1
Equate coefficients and solve for a M1
Obtain final answer $a = \frac{1}{\sqrt{2}}$, or exact equivalent A1 [4]
- (ii) Use correct method and value of a to find the first two terms of the expansion $(1+ax)^{-2}$ M1
Obtain $1 - \sqrt{2}x$, or equivalent A1 ✓
Obtain term $\frac{3}{2}x^2$ A1 ✓ [3]
[Symbolic coefficients, e.g. $\binom{-2}{1}a$, are not sufficient for the first B marks]
[The f.t. is solely on the value of a .]

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- 5 (i) Use correct quotient or chain rule M1
Obtain the given answer correctly having shown sufficient working A1 [2]
- (ii) Use a valid method, e.g. multiply numerator and denominator by $\sec x + \tan x$, and a version of Pythagoras to justify the given identity B1 [1]
- (iii) Substitute, expand $(\sec x + \tan x)^2$ and use Pythagoras once M1
Obtain given identity A1 [2]
- (iv) Obtain integral $2 \tan x - x + 2 \sec x$ B1
Use correct limits correctly in an expression of the form $a \tan x + bx + c \sec x$, or equivalent, where $abc \neq 0$ M1
Obtain the given answer correctly A1 [3]
- 6 Separate variables correctly and attempt integration of one side B1
Obtain term $\ln x$ B1
State or imply $\frac{1}{1-y^2} \equiv \frac{A}{1-y} + \frac{B}{1+y}$ and use a relevant method to find A or B M1
Obtain $A = \frac{1}{2}, B = \frac{1}{2}$
Integrate and obtain $-\frac{1}{2} \ln(1-y) + \frac{1}{2} \ln(1+y)$, or equivalent A1 ✓
[If the integral is directly stated as $k_1 \ln\left(\frac{1+y}{1-y}\right)$ or $k_2 \ln\left(\frac{1-y}{1+y}\right)$ give M1, and then A2 for $k_1 = \frac{1}{2}$ or $k_2 = -\frac{1}{2}$]
Evaluate a constant, or use limits $x = 2, y = 0$ in a solution containing terms $a \ln x, b \ln(1-y)$ and $c \ln(1+y)$, where $abc \neq 0$ M1
[This M mark is not available if the integral of $1/(1-y^2)$ is initially taken to be of the form $k \ln(1-y^2)$]
Obtain solution in any correct form, e.g. $\frac{1}{2} \ln\left(\frac{1+y}{1-y}\right) = \ln x - \ln 2$ A1
Rearrange and obtain $y = \frac{x^2 - 4}{x^2 + 4}$, or equivalent, free of logarithms A1 [8]
- 7 (i) EITHER: State or imply $\frac{1}{x} + \frac{1}{y} \frac{dy}{dx}$ as derivative of $\ln xy$, or equivalent B1
State or imply $3y^2 \frac{dy}{dx}$ as derivative of y^3 , or equivalent B1
Equate derivative of LHS to zero and solve for $\frac{dy}{dx}$ M1
Obtain the given answer A1
OR Obtain $xy = \exp(1+y^3)$ and state or imply $y + x \frac{dy}{dx}$ as derivative of xy B1
State or imply $3y^2 \frac{dy}{dx} \exp(1+y^3)$ as derivative of $(1+y^3)$ B1
Equate derivatives and solve for $\frac{dy}{dx}$ M1
Obtain the given answer A1 [4]
[The M1 is dependent on at least one of the B marks being earned]
- (ii) Equate denominator to zero and solve for y M1*
Obtain $y = 0.693$ only A1
Substitute found value in the equation and solve for x M1(dep*)
Obtain $x = 5.47$ only A1 [4]

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- 8 (i) Use correct product or quotient rule and use chain rule at least once M1
Obtain derivative in any correct form A1
Equate derivative to zero and solve an equation with at least two non-zero terms for real x M1
Obtain answer $x = \frac{1}{\sqrt{2}}$, or exact equivalent A1 [4]
- (ii) State a suitable equation, e.g. $\alpha = \sqrt{(\ln(4 + 8\alpha^2))}$ B1
Rearrange to reach $e^{\alpha^2} = 4 + 8\alpha^2$ B1
Obtain $\frac{1}{2} = e^{-\frac{1}{2}\alpha^2} \sqrt{(1 + 2\alpha^2)}$, or work *vice versa* B1 [3]
- (iii) Use the iterative formula correctly at least once M1
Obtain final answer 1.86 A1
Show sufficient iterations to 4 d.p. to justify 1.86 to 2 d.p., or show there is a sign change in the interval (1.855, 1.865) A1 [3]
- 9 (i) *EITHER* Substitute $x = 1 + \sqrt{2}i$ and attempt the expansions of the x^2 and x^4 terms M1
Use $i^2 = -1$ correctly at least once B1
Complete the verification A1
State second root $1 - \sqrt{2}i$ B1
OR 1 State second root $1 - \sqrt{2}i$ B1
Carry out a complete method for finding a quadratic factor with zeros $1 \pm \sqrt{2}i$ M1
Obtain $x^2 - 2x + 3$, or equivalent A1
Show that the division of $p(x)$ by $x^2 - 2x + 3$ gives zero remainder and complete the verification A1
OR 2 Substitute $x = 1 + \sqrt{2}i$ and use correct method to express x^2 and x^4 in polar form M1
Obtain x^2 and x^4 in any correct polar form (allow decimals here) B1
Complete an exact verification A1
State second root $1 - \sqrt{2}i$, or its polar equivalent (allow decimals here) B1 [4]
- (ii) Carry out a complete method for finding a quadratic factor with zeros $1 \pm \sqrt{2}i$ M1*
Obtain $x^2 - 2x + 3$, or equivalent A1
Attempt division of $p(x)$ by $x^2 - 2x + 3$ reaching a partial quotient $x^2 + kx$, or equivalent M1 (dep*)
Obtain quadratic factor $x^2 - 2x + 2$ A1
Find the zeros of the second quadratic factor, using $i^2 = -1$ M1 (dep*)
Obtain roots $-1 + i$ and $-1 - i$ A1 [6]
[The second M1 is earned if inspection reaches an unknown factor $x^2 + Bx + C$ and an equation in B and/or C , or an unknown factor $Ax^2 + Bx + (6/3)$ and an equation in A and/or B]
[If part (i) is attempted by the *OR 1* method, then an attempt at part (ii) which uses or quotes relevant working or results obtained in part (i) should be marked using the scheme for part (ii)]

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- 10 (i) *EITHER* Use scalar product of relevant vectors, or subtract point equations to form two equations in a, b, c , e.g. $a - 5b - 3c = 0$ and $a - b - 3c = 0$ M1*
- State two correct equations in a, b, c A1
- Solve simultaneous equations and find one ratio, e.g. $a : c$, or $b = 0$ M1 (dep*)
- Obtain $a : b : c = 3 : 0 : 1$, or equivalent A1
- Substitute a relevant point in $3x + z = d$ and evaluate d M1 (dep*)
- Obtain equation $3x + z = 13$, or equivalent A1
- OR 1* Attempt to calculate vector product of relevant vectors, e.g. $(\mathbf{i} - 5\mathbf{j} - 3\mathbf{k}) \times (\mathbf{i} - \mathbf{j} - 3\mathbf{k})$ M2*
- Obtain 2 correct components of the product A1
- Obtain correct product, e.g. $12\mathbf{i} + 4\mathbf{k}$ A1
- Substitute a relevant point in $12x + 4z = d$ and evaluate d M1 (dep*)
- Obtain $3x + z = 13$, or equivalent A1
- OR 2* Attempt to form 2-parameter equation for the plane with relevant vectors M2*
- State a correct equation e.g. $\mathbf{r} = 3\mathbf{i} - 2\mathbf{j} + 4\mathbf{k} + \lambda(\mathbf{i} - 5\mathbf{j} - 3\mathbf{k}) + \mu(\mathbf{i} - \mathbf{j} - 3\mathbf{k})$ A1
- State 3 equations in x, y, z, λ and μ A1
- Eliminate λ and μ M1 (dep*)
- Obtain equation $3x + z = 13$, or equivalent A1 [6]
- (ii) *EITHER* Find $\overrightarrow{CP}$ for a point P on AB with a parameter t , e.g. $2\mathbf{i} + 3\mathbf{j} + 7\mathbf{k} + t(-\mathbf{i} + \mathbf{j} + 3\mathbf{k})$ B1 ✓
- Either:* Equate scalar product $\overrightarrow{CP}, \overrightarrow{AB}$ to zero and form an equation in t
- Or 1:* Equate derivative for CP^2 (or CP) to zero and form an equation in t M1
- Or 2:* Use Pythagoras in triangle CPA (or CPB) and form an equation in t A1
- Solve and obtain correct value of t , e.g. $t = -2$ A1
- Carry out a complete method for finding the length of CP M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 1* State $\overrightarrow{AC}$ (or $\overrightarrow{BC}$) and $\overrightarrow{AB}$ in component form B1 ✓
- Using a relevant scalar product find the cosine of CAB (or CBA) M1
- Obtain $\cos CAB = -\frac{22}{\sqrt{11} \cdot \sqrt{62}}$, or $\cos CBA = \frac{33}{\sqrt{11} \cdot \sqrt{117}}$, or equivalent A1
- Use trig to find the length of the perpendicular M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 2* State $\overrightarrow{AC}$ (or $\overrightarrow{BC}$) and $\overrightarrow{AB}$ in component form B1 ✓
- Using a relevant scalar product find the length of the projection AC (or BC) on AB M1
- Obtain answer $2\sqrt{11}$ (or), $3\sqrt{11}$ or equivalent A1
- Use Pythagoras to find the length of the perpendicular M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 3* State $\overrightarrow{AC}$ (or $\overrightarrow{BC}$) and $\overrightarrow{AB}$ in component form B1 ✓
- Calculate their vector product, e.g. $(-2\mathbf{i} - 3\mathbf{j} - 7\mathbf{k}) \times (-\mathbf{i} + \mathbf{j} + 3\mathbf{k})$ M1
- Obtain correct product, e.g. $-2\mathbf{i} + 13\mathbf{j} - 5\mathbf{k}$ A1
- Divide modulus of the product by the modulus of $\overrightarrow{AB}$ M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 4* State two of $\overrightarrow{AB}, \overrightarrow{BC}$ and $\overrightarrow{AC}$ in component form B1 ✓
- Use cosine formula in triangle ABC to find $\cos A$ or $\cos B$ M1
- Obtain $\cos A = -\frac{44}{2\sqrt{11} \cdot \sqrt{62}}$, or $\cos B = \frac{66}{2\sqrt{11} \cdot \sqrt{117}}$ A1
- Use trig to find the length of the perpendicular M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1 [5]
- [The f.t is on $\overrightarrow{AB}$]

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Make reasonable solution attempt at a 3-term quadratic, or solve two linear equations M1
Obtain critical values $x = \frac{2}{5}$ and $x = 4$ A1
State answer $\frac{2}{5} < x < 4$ A1
- OR* Obtain critical value $x = \frac{2}{5}$ or $x = 4$ from a graphical method, or by inspection, or by solving a linear equation or inequality B1
Obtain critical values $x = \frac{2}{5}$ and $x = 4$ B2
State answer $\frac{2}{5} < x < 4$ B1 [4]
[Do not condone $\leq$ for $<$.]
- 2 *EITHER* Use laws of indices correctly and solve for 5^x or for 5^{-x} or for 5^{x-1} M1
Obtain 5^x or for 5^{-x} or for 5^{x-1} in any correct form, e.g. $5^x = \frac{5}{1-1/5}$ A1
Use correct method for solving $5^x = a$, or $5^{-x} = a$, or $5^{x-1} = a$, where $a > 0$ M1
Obtain answer $x = 1.14$ A1
- OR* Use an appropriate iterative formula, e.g. $x_{n+1} = \frac{\ln(5^{x-1}+5)}{\ln 5}$, correctly, at least once M1
Obtain answer 1.14 A1
Show sufficient iterations to at least 3 d.p. to justify 1.14 to 2 d.p., or show there is a sign change in the interval (1.135, 1.145) A1
Show there is no other root A1 [4]
[For the solution $x = 1.14$ with no relevant working give B1, and a further B1 if 1.14 is shown to be the only solution.]
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Obtain a correct equation in any form A1
Use trig. formula to obtain an equation in $\tan \theta$ (or $\cos \theta$, $\sin \theta$ or $\cot \theta$) M1
Obtain $\tan \theta = \frac{\sqrt{6}-1}{1-\sqrt{2}}$, or equivalent (or find $\cos \theta$, $\sin \theta$ or $\cot \theta$) A1
Obtain answer $\theta = 105.9^\circ$, and no others in the given interval A1 [5]
[Ignore answers outside the given material]
- 4 (i) Obtain correct unsimplified terms in x and x^3 B1 + B1
Equate coefficients and solve for a M1
Obtain final answer $a = \frac{1}{\sqrt{2}}$, or exact equivalent A1 [4]
- (ii) Use correct method and value of a to find the first two terms of the expansion $(1+ax)^{-2}$ M1
Obtain $1 - \sqrt{2}x$, or equivalent A1 ✓
Obtain term $\frac{3}{2}x^2$ A1 ✓ [3]
[Symbolic coefficients, e.g. $\binom{-2}{1}a$, are not sufficient for the first B marks]
[The f.t. is solely on the value of a .]

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- 5 (i) Use correct quotient or chain rule M1
Obtain the given answer correctly having shown sufficient working A1 [2]
- (ii) Use a valid method, e.g. multiply numerator and denominator by $\sec x + \tan x$, and a version of Pythagoras to justify the given identity B1 [1]
- (iii) Substitute, expand $(\sec x + \tan x)^2$ and use Pythagoras once M1
Obtain given identity A1 [2]
- (iv) Obtain integral $2 \tan x - x + 2 \sec x$ B1
Use correct limits correctly in an expression of the form $a \tan x + bx + c \sec x$, or equivalent, where $abc \neq 0$ M1
Obtain the given answer correctly A1 [3]
- 6 Separate variables correctly and attempt integration of one side B1
Obtain term $\ln x$ B1
State or imply $\frac{1}{1-y^2} \equiv \frac{A}{1-y} + \frac{B}{1+y}$ and use a relevant method to find A or B M1
Obtain $A = \frac{1}{2}, B = \frac{1}{2}$
Integrate and obtain $-\frac{1}{2} \ln(1-y) + \frac{1}{2} \ln(1+y)$, or equivalent A1 ✓
[If the integral is directly stated as $k_1 \ln\left(\frac{1+y}{1-y}\right)$ or $k_2 \ln\left(\frac{1-y}{1+y}\right)$ give M1, and then A2 for $k_1 = \frac{1}{2}$ or $k_2 = -\frac{1}{2}$]
Evaluate a constant, or use limits $x = 2, y = 0$ in a solution containing terms $a \ln x, b \ln(1-y)$ and $c \ln(1+y)$, where $abc \neq 0$ M1
[This M mark is not available if the integral of $1/(1-y^2)$ is initially taken to be of the form $k \ln(1-y^2)$]
Obtain solution in any correct form, e.g. $\frac{1}{2} \ln\left(\frac{1+y}{1-y}\right) = \ln x - \ln 2$ A1
Rearrange and obtain $y = \frac{x^2 - 4}{x^2 + 4}$, or equivalent, free of logarithms A1 [8]
- 7 (i) EITHER: State or imply $\frac{1}{x} + \frac{1}{y} \frac{dy}{dx}$ as derivative of $\ln xy$, or equivalent B1
State or imply $3y^2 \frac{dy}{dx}$ as derivative of y^3 , or equivalent B1
Equate derivative of LHS to zero and solve for $\frac{dy}{dx}$ M1
Obtain the given answer A1
OR Obtain $xy = \exp(1+y^3)$ and state or imply $y + x \frac{dy}{dx}$ as derivative of xy B1
State or imply $3y^2 \frac{dy}{dx} \exp(1+y^3)$ as derivative of $(1+y^3)$ B1
Equate derivatives and solve for $\frac{dy}{dx}$ M1
Obtain the given answer A1 [4]
[The M1 is dependent on at least one of the B marks being earned]
- (ii) Equate denominator to zero and solve for y M1*
Obtain $y = 0.693$ only A1
Substitute found value in the equation and solve for x M1(dep*)
Obtain $x = 5.47$ only A1 [4]

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- 8 (i) Use correct product or quotient rule and use chain rule at least once M1
Obtain derivative in any correct form A1
Equate derivative to zero and solve an equation with at least two non-zero terms for real x M1
Obtain answer $x = \frac{1}{\sqrt{2}}$, or exact equivalent A1 [4]
- (ii) State a suitable equation, e.g. $\alpha = \sqrt{(\ln(4 + 8\alpha^2))}$ B1
Rearrange to reach $e^{\alpha^2} = 4 + 8\alpha^2$ B1
Obtain $\frac{1}{2} = e^{-\frac{1}{2}\alpha^2} \sqrt{(1 + 2\alpha^2)}$, or work *vice versa* B1 [3]
- (iii) Use the iterative formula correctly at least once M1
Obtain final answer 1.86 A1
Show sufficient iterations to 4 d.p. to justify 1.86 to 2 d.p., or show there is a sign change in the interval (1.855, 1.865) A1 [3]
- 9 (i) *EITHER* Substitute $x = 1 + \sqrt{2}i$ and attempt the expansions of the x^2 and x^4 terms M1
Use $i^2 = -1$ correctly at least once B1
Complete the verification A1
State second root $1 - \sqrt{2}i$ B1
OR 1 State second root $1 - \sqrt{2}i$ B1
Carry out a complete method for finding a quadratic factor with zeros $1 \pm \sqrt{2}i$ M1
Obtain $x^2 - 2x + 3$, or equivalent A1
Show that the division of $p(x)$ by $x^2 - 2x + 3$ gives zero remainder and complete the verification A1
OR 2 Substitute $x = 1 + \sqrt{2}i$ and use correct method to express x^2 and x^4 in polar form M1
Obtain x^2 and x^4 in any correct polar form (allow decimals here) B1
Complete an exact verification A1
State second root $1 - \sqrt{2}i$, or its polar equivalent (allow decimals here) B1 [4]
- (ii) Carry out a complete method for finding a quadratic factor with zeros $1 \pm \sqrt{2}i$ M1*
Obtain $x^2 - 2x + 3$, or equivalent A1
Attempt division of $p(x)$ by $x^2 - 2x + 3$ reaching a partial quotient $x^2 + kx$, or equivalent M1 (dep*)
Obtain quadratic factor $x^2 - 2x + 2$ A1
Find the zeros of the second quadratic factor, using $i^2 = -1$ M1 (dep*)
Obtain roots $-1 + i$ and $-1 - i$ A1 [6]
[The second M1 is earned if inspection reaches an unknown factor $x^2 + Bx + C$ and an equation in B and/or C , or an unknown factor $Ax^2 + Bx + (6/3)$ and an equation in A and/or B]
[If part (i) is attempted by the *OR 1* method, then an attempt at part (ii) which uses or quotes relevant working or results obtained in part (i) should be marked using the scheme for part (ii)]

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- 10 (i) *EITHER* Use scalar product of relevant vectors, or subtract point equations to form two equations in a, b, c , e.g. $a - 5b - 3c = 0$ and $a - b - 3c = 0$ M1*
- State two correct equations in a, b, c A1
- Solve simultaneous equations and find one ratio, e.g. $a : c$, or $b = 0$ M1 (dep*)
- Obtain $a : b : c = 3 : 0 : 1$, or equivalent A1
- Substitute a relevant point in $3x + z = d$ and evaluate d M1 (dep*)
- Obtain equation $3x + z = 13$, or equivalent A1
- OR 1* Attempt to calculate vector product of relevant vectors, e.g. $(\mathbf{i} - 5\mathbf{j} - 3\mathbf{k}) \times (\mathbf{i} - \mathbf{j} - 3\mathbf{k})$ M2*
- Obtain 2 correct components of the product A1
- Obtain correct product, e.g. $12\mathbf{i} + 4\mathbf{k}$ A1
- Substitute a relevant point in $12x + 4z = d$ and evaluate d M1 (dep*)
- Obtain $3x + z = 13$, or equivalent A1
- OR 2* Attempt to form 2-parameter equation for the plane with relevant vectors M2*
- State a correct equation e.g. $\mathbf{r} = 3\mathbf{i} - 2\mathbf{j} + 4\mathbf{k} + \lambda(\mathbf{i} - 5\mathbf{j} - 3\mathbf{k}) + \mu(\mathbf{i} - \mathbf{j} - 3\mathbf{k})$ A1
- State 3 equations in x, y, z, λ and μ A1
- Eliminate λ and μ M1 (dep*)
- Obtain equation $3x + z = 13$, or equivalent A1 [6]
- (ii) *EITHER* Find $\overrightarrow{CP}$ for a point P on AB with a parameter t , e.g. $2\mathbf{i} + 3\mathbf{j} + 7\mathbf{k} + t(-\mathbf{i} + \mathbf{j} + 3\mathbf{k})$ B1 ✓
- Either:* Equate scalar product $\overrightarrow{CP}, \overrightarrow{AB}$ to zero and form an equation in t
- Or 1:* Equate derivative for CP^2 (or CP) to zero and form an equation in t M1
- Or 2:* Use Pythagoras in triangle CPA (or CPB) and form an equation in t A1
- Solve and obtain correct value of t , e.g. $t = -2$ A1
- Carry out a complete method for finding the length of CP M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 1* State $\overrightarrow{AC}$ (or $\overrightarrow{BC}$) and $\overrightarrow{AB}$ in component form B1 ✓
- Using a relevant scalar product find the cosine of CAB (or CBA) M1
- Obtain $\cos CAB = -\frac{22}{\sqrt{11} \cdot \sqrt{62}}$, or $\cos CBA = \frac{33}{\sqrt{11} \cdot \sqrt{117}}$, or equivalent A1
- Use trig to find the length of the perpendicular M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 2* State $\overrightarrow{AC}$ (or $\overrightarrow{BC}$) and $\overrightarrow{AB}$ in component form B1 ✓
- Using a relevant scalar product find the length of the projection AC (or BC) on AB M1
- Obtain answer $2\sqrt{11}$ (or), $3\sqrt{11}$ or equivalent A1
- Use Pythagoras to find the length of the perpendicular M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 3* State $\overrightarrow{AC}$ (or $\overrightarrow{BC}$) and $\overrightarrow{AB}$ in component form B1 ✓
- Calculate their vector product, e.g. $(-2\mathbf{i} - 3\mathbf{j} - 7\mathbf{k}) \times (-\mathbf{i} + \mathbf{j} + 3\mathbf{k})$ M1
- Obtain correct product, e.g. $-2\mathbf{i} + 13\mathbf{j} - 5\mathbf{k}$ A1
- Divide modulus of the product by the modulus of $\overrightarrow{AB}$ M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1
- OR 4* State two of $\overrightarrow{AB}, \overrightarrow{BC}$ and $\overrightarrow{AC}$ in component form B1 ✓
- Use cosine formula in triangle ABC to find $\cos A$ or $\cos B$ M1
- Obtain $\cos A = -\frac{44}{2\sqrt{11} \cdot \sqrt{62}}$, or $\cos B = \frac{66}{2\sqrt{11} \cdot \sqrt{117}}$ A1
- Use trig to find the length of the perpendicular M1
- Obtain answer $3\sqrt{2}$ (4.24), or equivalent A1 [5]
- [The f.t is on $\overrightarrow{AB}$]

CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Level

MARK SCHEME for the October/November 2012 series

9709 MATHEMATICS

9709/33

Paper 3, maximum raw mark 75

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge will not enter into discussions about these mark schemes.

Cambridge is publishing the mark schemes for the October/November 2012 series for most IGCSE, GCE Advanced Level and Advanced Subsidiary Level components and some Ordinary Level components.

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Mark Scheme Notes

Marks are of the following three types:

- M Method mark, awarded for a valid method applied to the problem. Method marks are not lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.
- A Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated method mark is earned (or implied).
- B Mark for a correct result or statement independent of method marks.

When a part of a question has two or more “method” steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly when there are several B marks allocated. The notation DM or DB (or dep*) is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.

The symbol ∇ implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only. A and B marks are not given for fortuitously “correct” answers or results obtained from incorrect working.

Note: B2 or A2 means that the candidate can earn 2 or 0.

B2/1/0 means that the candidate can earn anything from 0 to 2.

The marks indicated in the scheme may not be subdivided. If there is genuine doubt whether a candidate has earned a mark, allow the candidate the benefit of the doubt. Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored.

Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise.

For a numerical answer, allow the A or B mark if a value is obtained which is correct to 3 s.f., or which would be correct to 3 s.f. if rounded (1 d.p. in the case of an angle). As stated above, an A or B mark is not given if a correct numerical answer arises fortuitously from incorrect working. For Mechanics questions, allow A or B marks for correct answers which arise from taking g equal to 9.8 or 9.81 instead of 10.

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The following abbreviations may be used in a mark scheme or used on the scripts:

AEF	Any Equivalent Form (of answer is equally acceptable)
AG	Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)
BOD	Benefit of Doubt (allowed when the validity of a solution may not be absolutely clear)
CAO	Correct Answer Only (emphasising that no “follow through” from a previous error is allowed)
CWO	Correct Working Only – often written by a ‘fortuitous’ answer
ISW	Ignore Subsequent Working
MR	Misread
PA	Premature Approximation (resulting in basically correct work that is insufficiently accurate)
SOS	See Other Solution (the candidate makes a better attempt at the same question)
SR	Special Ruling (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)

Penalties

MR –1	A penalty of MR –1 is deducted from A or B marks when the data of a question or part question are genuinely misread and the object and difficulty of the question remain unaltered. In this case all A and B marks then become “follow through ✓” marks. MR is not applied when the candidate misreads his own figures – this is regarded as an error in accuracy. An MR –2 penalty may be applied in particular cases if agreed at the coordination meeting.
PA –1	This is deducted from A or B marks in the case of premature approximation. The PA –1 penalty is usually discussed at the meeting.

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- 1 State or imply $\ln e = 1$ B1
 Apply at least one logarithm law for product or quotient correctly (or exponential equivalent) M1
 Obtain $x + 5 = ex$ or equivalent and hence $\frac{5}{e-1}$ A1 [3]
- 2 (i) State or imply $R = 25$ B1
 Use correct trigonometric formula to find α M1
 Obtain 16.26° **with no errors seen** A1 [3]
- (ii) Evaluate of $\sin^{-1} \frac{17}{R}$ ($= 42.84\dots^\circ$) M1
 Obtain answer 59.1° A1 [2]
- 3 (i) Either Use correct quotient rule or equivalent to obtain

$$\frac{dx}{dt} = \frac{4(2t+3)-8t}{(2t+3)^2} \text{ or equivalent} \quad \text{B1}$$
 Obtain $\frac{dy}{dt} = \frac{4}{2t+3}$ or equivalent B1
 Use $\frac{dy}{dx} = \frac{\frac{dy}{dt}}{\frac{dx}{dt}}$ or equivalent M1
 Obtain $\frac{1}{3}(2t+3)$ or similarly simplified equivalent A1
- Or Express t in terms of x or y e.g. $t = \frac{3x}{4-2x}$ B1
 Obtain Cartesian equation e.g. $y = 2\ln\left(\frac{6}{2-x}\right)$ B1
 Differentiate and obtain $\frac{dy}{dx} = \frac{2}{2-x}$ M1
 Obtain $\frac{1}{3}(2t+3)$ or similarly simplified equivalent A1 [4]
- (ii) Obtain $2t = 3$ or $t = \frac{3}{2}$ B1
 Substitute in expression for $\frac{dy}{dx}$ and obtain 2 B1 [2]

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- 4 Separate variables correctly and integrate one side M1
Obtain $\ln y = \dots$ or equivalent A1
Obtain $= 3 \ln(x^2 + 4)$ or equivalent A1
Evaluate a constant or use $x = 0, y = 32$ as limits in a solution M1
containing terms $a \ln y$ and $b \ln(x^2 + 4)$
Obtain $\ln y = 3 \ln(x^2 + 4) + \ln 32 - 3 \ln 4$ or equivalent A1
Obtain $y = \frac{1}{2}(x^2 + 4)$ or equivalent A1 [6]
- 5 (i) Either Use correct product rule M1
Obtain $3e^{-2x} - 6xe^{-2x}$ or equivalent A1
Substitute $-\frac{1}{2}$ and obtain $6e$ A1
Or Take $\ln$ of both sides and use implicit differentiation correctly M1
Obtain $\frac{dy}{dx} = y \left(\frac{1}{x} - 2 \right)$ or equivalent A1
Substitute $-\frac{1}{2}$ and obtain $6e$ A1 [3]
- (ii) Use integration by parts to reach $kxe^{-2x} \pm \int ke^{-2x} dx$ M1
Obtain $-\frac{3}{2}xe^{-2x} + \int \frac{3}{2}e^{-2x} dx$ or equivalent A1
Obtain $-\frac{3}{2}xe^{-2x} - \frac{3}{4}e^{-2x}$ or equivalent A1
Substitute correct limits correctly DM1
Obtain $-\frac{3}{4}$ with no errors or inexact work seen A1 [5]
- 6 (i) Find y for $x = -2$ M1
Obtain 0 and conclude that $\alpha = -2$ A1 [2]
- (ii) Either Find cubic factor by division or inspection or equivalent M1
Obtain $x^3 + 2x - 8$ A1
Rearrange to confirm given equation $x = \sqrt[3]{8 - 2x}$ A1
Or Derive cubic factor from given equation and form product with $(x - \alpha)$ M1
 $(x + 2)(x^3 + 2x - 8)$ A1
Obtain quartic $x^4 + 2x^3 + 2x^2 - 4x - 16 (= 0)$ A1
Or Derive cubic factor from given equation and divide the quartic by the cubic M1
 $(x^4 + 2x^3 + 2x^2 - 4x - 16) \div (x^3 + 2x - 8)$ A1
Obtain correct quotient and zero remainder A1 [3]
- (iii) Use the given iterative formula correctly at least once M1
Obtain final answer 1.67 A1
Show sufficient iterations to at least 4 d.p. to justify answer 1.67 to 2 d.p. or show there is a change of sign in interval (1.665, 1.675) A1 [3]

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- 7 (i) State or imply $du = 2\cos 2x \, dx$ or equivalent B1
Express integrand in terms of u and du M1
Obtain $\int_2^1 u^3(1-u^2) \, du$ or equivalent A1
Integration to obtain an integral of the form $k_1 u^4 + k_2 u^6, k_1, k_2 \neq 0$ M1
Use limits 0 and 1 or (if reverting to x) 0 and $\frac{1}{4}\pi$ correctly DM1
Obtain $\frac{1}{24}$, or equivalent A1 [6]
- (ii) Use 40 and upper limit from part (i) in appropriate calculation M1
Obtain $k = 10$ with no errors seen A1 [2]
- 8 (i) State or imply general point of either line has coordinates $(5 + s, 1 - s, -4 + 3s)$ or $(p + 2t, 4 + 5t, -2 - 4t)$ B1
Solve simultaneous equations and find s and t M1
Obtain $s = 2$ and $t = -1$ or equivalent in terms of p A1
Substitute in third equation to find $p = 9$ A1
State point of intersection is $(7, -1, 2)$ A1 [5]
- (ii) Either Use scalar product to obtain a relevant equation in a, b, c
e.g. $a - b + 3c = 0$ or $2a + 5b - 4c = 0$ M1
State two correct equations in a, b, c A1
Solve simultaneous equations to obtain at least one ratio DM1
Obtain $a : b : c = -11 : 10 : 7$ or equivalent A1
Obtain equation $-11x + 10y + 7z = -73$ or equivalent with integer coefficients A1
- Or 1 Calculate vector product of $\begin{pmatrix} 1 \\ -1 \\ 3 \end{pmatrix}$ and $\begin{pmatrix} 2 \\ 5 \\ -4 \end{pmatrix}$ M1
Obtain two correct components of the product A1
Obtain correct $\begin{pmatrix} -11 \\ 10 \\ 7 \end{pmatrix}$ or equivalent A1
Substitute coordinates of a relevant point in $\mathbf{r} \cdot \mathbf{n} = d$ to find d DM1
Obtain equation $-11x + 10y + 7z = -73$ or equivalent with integer coefficients A1
- Or 2 Using relevant vectors, form correctly a two-parameter equation for the plane M1
Obtain $\mathbf{r} = \begin{pmatrix} 5 \\ 1 \\ -4 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ -1 \\ 3 \end{pmatrix} + \mu \begin{pmatrix} 2 \\ 5 \\ -4 \end{pmatrix}$ or equivalent A1
State three equations in x, y, z, λ, μ A1
Eliminate λ and μ DM1
Obtain $11x - 10y - 7z = 73$ or equivalent with integer coefficients A1 [5]

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- 9 (i) State or imply form $\frac{A}{3-x} + \frac{Bx+C}{1+x^2}$ B1
 Use relevant method to determine a constant M1
 Obtain $A = 6$ A1
 Obtain $B = -2$ A1
 Obtain $C = 1$ A1 [5]
- (ii) Either Use correct method to obtain first two terms of expansion
 of $(3-x)^{-1}$ or $\left(1 - \frac{1}{3}x\right)^{-1}$ or $(1+x^2)^{-1}$ M1
 Obtain $\frac{A}{3}\left(1 + \frac{1}{3}x + \frac{1}{9}x^2 + \frac{1}{27}x^3\right)$ A1
 Obtain $(Bx+C)(1-x^2)$ A1
 Obtain sufficient terms of the product $(Bx+C)(1-x^2)$, $B, C \neq 0$ and add the two expansions M1
 Obtain final answer $3 - \frac{4}{3}x - \frac{7}{9}x^2 + \frac{56}{27}x^3$ A1
- Or Use correct method to obtain first two terms of expansion
 of $(3-x)^{-1}$ or $\left(1 - \frac{1}{3}x\right)^{-1}$ or $(1+x^2)^{-1}$ M1
 Obtain $\frac{1}{3}\left(1 + \frac{1}{3}x + \frac{1}{9}x^2 + \frac{1}{27}x^3\right)$ A1
 Obtain $(1-x^2)$ A1
 Obtain sufficient terms of the product of the three factors M1
 Obtain final answer $3 - \frac{4}{3}x - \frac{7}{9}x^2 + \frac{56}{27}x^3$ A1 [5]
- 10 (a) Expand and simplify as far as $i\omega^2 = -8i$ or equivalent B1
 Obtain first answer $i\sqrt{8}$, or equivalent B1
 Obtain second answer $-i\sqrt{8}$, or equivalent and no others B1 [3]
- (b) (i) Draw circle with centre in first quadrant M1
 Draw correct circle with interior shaded or indicated A1 [2]
- (ii) Identify ends of diameter corresponding to line through origin and centre M1
 Obtain $p = 3.66$ and $q = 7.66$ A1
 Show tangents from origin to circle M1
 Evaluate $\sin^{-1}\left(\frac{1}{4}\sqrt{2}\right)$ M1
 Obtain $\alpha = \frac{1}{4}\pi - \sin^{-1}\left(\frac{1}{4}\sqrt{2}\right)$ or equivalent and hence 0.424 A1
 Obtain $\beta = \frac{1}{4}\pi + \sin^{-1}\left(\frac{1}{4}\sqrt{2}\right)$ or equivalent and hence 1.15 A1 [6]