MARKSCHEME

November 2006

MATHEMATICS

Higher Level

Paper 2

14 pages

Instructions to Examiners

Abbreviations

M Marks awarded for attempting to use a correct **Method**; working must be seen.

(M) Marks awarded for **Method**; may be implied by **correct** subsequent working.

A Marks awarded for an **Answer** or for **Accuracy**: often dependent on preceding ***M*** marks.

(A) Marks awarded for an **Answer** or for **Accuracy**; may be implied by **correct** subsequent working.

R Marks awarded for clear **Reasoning**.

N Marks awarded for **correct** answers if **no** working shown (or working which gains no other marks).

AG Answer given in the question and so no marks are awarded.

Using the markscheme

1 General

Write the marks in red on candidates' scripts, in the right hand margin.

- Show the **breakdown** of individual marks awarded using the abbreviations ***M1***, ***A1***, *etc*.
- Write down the total for each **question** (at the end of the question) and **circle** it.

2 Method and Answer/Accuracy marks

- Do **not** automatically award full marks for a correct answer; all working **must** be checked, and marks awarded according to the markscheme.
- It is not possible to award ***M0*** followed by ***A1***, as ***A*** mark(s) depend on the preceding ***M*** mark(s), if any.
- Where ***M*** and ***A*** marks are noted on the same line, *e.g.* ***M1A1***, this usually means ***M1*** for an **attempt** to use an appropriate method (*e.g.* substitution into a formula) and ***A1*** for using the **correct** values.
- Where the markscheme specifies ***(M2)***, ***N3***, *etc.*, do **not** split the marks.
- Once a correct answer to a question or part-question is seen, ignore further working.

3 *N* marks

*Award **N** marks for **correct** answers where there is **no** working, (or working which gains no other marks).*

- Do **not** award a mixture of ***N*** and other marks.
- There may be fewer ***N*** marks available than the total of ***M***, ***A*** and ***R*** marks; this is deliberate as it penalizes candidates for not following the instruction to show their working.
- For consistency within the markscheme, ***N*** marks are noted for every part, even when these match the mark breakdown. In these cases, the marks may be recorded in either form *e.g.* ***A2*** or ***N2***.

4 Implied marks

Implied marks appear in ***brackets e.g. (M1)****, and can only be awarded if* ***correct*** *work is seen or if implied in subsequent working.*

- Normally the correct work is seen or implied in the next line.
- Marks **without** brackets can only be awarded for work that is **seen**.

5 Follow through marks

Follow through ***(FT)*** *marks are awarded where an incorrect answer from one* ***part*** *of a question is used correctly in* ***subsequent*** *part(s). To award* ***FT*** *marks,* ***there must be working present*** *and not just a final answer based on an incorrect answer to a previous part.*

- If the question becomes much simpler because of an error then use discretion to award fewer ***FT*** marks.
- If the error leads to an inappropriate value (*e.g.* $\sin\theta = 1.5$), do not award the mark(s) for the final answer(s).
- Within a question part, once an error is made, no further **dependent *A*** marks can be awarded, but ***M*** marks may be awarded if appropriate.
- Exceptions to this rule will be explicitly noted on the markscheme.

6 Mis-read

If a candidate incorrectly copies information from the question, this is a mis-read ***(MR)****. Apply a* ***MR*** *penalty of 1 mark to that question. Award the marks as usual and then write –1****(MR)*** *next to the total. Subtract 1 mark from the total for the question. A candidate should be penalized only once for a particular mis-read.*

- If the question becomes much simpler because of the ***MR***, then use discretion to award fewer marks.
- If the ***MR*** leads to an inappropriate value (*e.g.* $\sin\theta = 1.5$), do not award the mark(s) for the final answer(s).

7 Discretionary marks *(d)*

An examiner uses discretion to award a mark on the rare occasions when the markscheme does not cover the work seen. The mark should be labelled ***(d)*** *and a brief* ***note*** *written next to the mark explaining this decision.*

8 Alternative methods

Candidates will sometimes use methods other than those in the markscheme. Unless the question specifies a method, other correct methods should be marked in line with the markscheme. If in doubt, contact your team leader for advice.

- Alternative methods for complete questions are indicated by **METHOD 1**, **METHOD 2**, *etc*.
- Alternative solutions for part-questions are indicated by **EITHER** . . . **OR**.
- Where possible, alignment will also be used to assist examiners in identifying where these alternatives start and finish.

9 Alternative forms

Unless the question specifies otherwise, ***accept*** *equivalent forms.*

- As this is an international examination, accept all alternative forms of **notation**.
- In the markscheme, equivalent **numerical** and **algebraic** forms will generally be written in brackets immediately following the answer.
- In the markscheme, **simplified** answers, (which candidates often do not write in examinations), will generally appear in brackets. Marks should be awarded for either the form preceding the bracket or the form in brackets (if it is seen).

  Example: for differentiating $f(x) = 2\sin(5x-3)$, the markscheme gives:

  $f'(x) = \left(2\cos(5x-3)\right)5 \quad \left(=10\cos(5x-3)\right)$ ***A1***

  Award ***A1*** for $\left(2\cos(5x-3)\right)5$, even if $10\cos(5x-3)$ is not seen.

10 Accuracy of Answers

If the level of accuracy is specified in the question, a mark will be allocated for giving the answer to the required accuracy.

- **Rounding errors**: only applies to final answers not to intermediate steps.
- **Level of accuracy**: when this is not specified in the question the general rule applies: *unless otherwise stated in the question all numerical answers must be given exactly or correct to three significant figures*.

Candidates should be penalized ***once only IN THE PAPER*** *for an accuracy error* ***(AP)****. Award the marks as usual then write* ***(AP)*** *against the answer. On the* ***front*** *cover write –1****(AP).*** *Deduct 1 mark from the total for the paper, not the question*.

- If a final correct answer is incorrectly rounded, apply the ***AP***.
- If the level of accuracy is not specified in the question, apply the ***AP*** for correct answers not given to three significant figures.

If there is no working shown, and answers are given to the correct two significant figures, apply the ***AP***. However, do **not** accept answers to one significant figure without working.

11 Crossed out work

If a candidate has drawn a line through work on their examination script, or in some other way crossed out their work, do not award any marks for that work.

12 Examples

Exemplar material is available under examiner training on http://courses.triplealearning.co.uk. Please refer to this material before you start marking, and when you have any queries. Please also feel free to contact your Team Leader if you need further advice.

1. Part A

(a) Area of sector OAB $= \frac{1}{2}r^2\theta$ *A1*

Area of triangle OAB $= \frac{1}{2}r^2 \sin\theta$ *A1*

Shaded area $=$ Area of sector CAB – Area of triangle OAB *(M1)*

$= \frac{1}{2}r^2\theta - \frac{1}{2}r^2 \sin\theta$ *A1*

$= \frac{1}{2}r^2(\theta - \sin\theta)$ *AG* *N0*

[4 marks]

(b) Area of the major segment $=$ area of circle – shaded area *(M1)*

$= \pi r^2 - \frac{1}{2}r^2(\theta - \sin\theta) \quad \left(= r^2\left(\pi - \frac{\theta}{2} + \frac{\sin\theta}{2}\right)\right)$ *(M1)A1* *N3*

[3 marks]

(c) Given ratio of segments is $3:2$

METHOD 1

$\frac{3}{2}r^2(\theta - \sin\theta) = 2r^2\left(\pi - \frac{\theta}{2} + \sin\frac{\theta}{2}\right)$ *M1A1*

$\Rightarrow 3\theta - 3\sin\theta = 4\pi - 2\theta + 2\sin\theta$ *(A1)*

$\Rightarrow 5\theta - 5\sin\theta = 4\pi$

$\Rightarrow 5\sin\theta = 5\theta - 4\pi$ *A1*

$\Rightarrow \sin\theta = \theta - \frac{4\pi}{5}$ *AG* *N0*

METHOD 2

area of shaded region $= \frac{2}{5}\pi r^2$ *M1*

$\Rightarrow \frac{1}{2}r^2(\theta - \sin\theta) = \frac{2}{5}\pi r^2$ *A1*

$\Rightarrow 5(\theta - \sin\theta) = 4\pi$ *A1*

$\Rightarrow 5\theta - 5\sin\theta = 4\pi$ *A1*

$\Rightarrow \sin\theta = \theta - \frac{4}{5}\pi$ *AG*

[4 marks]

(d) $\theta = 2.82$ radians *A2*

[2 marks]

Sub-total [13 marks]

continued …

Question 1 continued

Part B

(a) If $n = 1$, then $(1)(1!) = (1+1)! - 1$ is true **A1**

Assume true for $n = k$

$\Rightarrow (1)(1!) + (2)(2!) + \ldots + (k)(k!) = (k+1)! - 1$ **M1A1**

Add the next term $(k+1)(k+1)!$ to both sides **M1**

$(1)(1!) + (2)(2!) + \ldots + (k)(k!) + (k+1)(k+1)! = (k+1)! - 1 + (k+1)(k+1)!$ **A1**

$= (k+1)!\,[1 + k + 1] - 1$ **A1**

$= (k+2)! - 1$ **A1**

True for $k \Rightarrow$ True for $k+1$ and since true for $n = 1$, result proved by mathematical induction. **R1**

[8 marks]

(b) $(n+1)! - 1 > 1000000000$ ***(M1)***

$(n+1)! > 1000000001$

from GDC minimum value of $n = 12$ **A2** ***N3***

[3 marks]

Sub-total [11 marks]

Total [24 marks]

2. Part A

(a) Let X be the number of yellow ribbons in the sample

$X \sim \mathrm{B}\left(10, \frac{1}{4}\right)$ ***(M1)***

$\Rightarrow \mathrm{E}(X) = 2.5$ ***A1*** ***N2***

[2 marks]

(b) $\mathrm{P}(X = 6) = \binom{10}{6}\left(\frac{1}{4}\right)^6\left(\frac{3}{4}\right)^4$ ***(M1)***

$= 0.0162$ ***A1*** ***N2***

[2 marks]

(c) $\mathrm{P}(X \geq 2) = 1 - \mathrm{P}(X \leq 1) = 1 - \left(\mathrm{P}(X = 0) + \mathrm{P}(X = 1)\right)$ ***(M1)***

$= 1 - \left(\frac{3}{4}\right)^{10} - 10\left(\frac{1}{4}\right)\left(\frac{3}{4}\right)^9$ ***(A1)***

$= 0.756$ ***A1*** ***N3***

[3 marks]

(d) $\mathrm{P}(X = x) = \binom{10}{x}\left(\frac{1}{4}\right)^x\left(\frac{3}{4}\right)^{10-x}$

Using GDC (or by substituting values of x into above) it is possible to calculate relevant probabilities. ***(M1)***

x	$\mathrm{P}(X = x)$
1	0.188
2	0.282
3	0.250

A2

From these values the most likely number of yellow ribbons is 2. ***A1*** ***N0***

[4 marks]

(e) The probability that a ribbon is yellow remains constant. ***R1***

[1 mark]

Sub-total [12 marks]

continued ...

Question 2 continued

Part B

(a) $\int_0^k \frac{x}{1+x^2}\,dx = 1$ ***M1***

$\left[\frac{1}{2}\ln(1+x^2)\right]_0^k = 1$ ***M1***

$\frac{1}{2}\ln(1+k^2) = 1$ ***A1***

$\ln(1+k^2) = 2$

$1+k^2 = e^2$ ***A1***

$k^2 = e^2 - 1$

$k = \sqrt{e^2 - 1}$ ***A1*** ***N0***

[5 marks]

(b) At the mode, $f(x)$ is a maximum ***R1***

The mode is 1 ***A1*** ***N1***

[2 marks]

(c) $P(1 \le X \le 2) = \int_1^2 \frac{x}{1+x^2}\,dx$ ***(M1)***

$= 0.458 \quad \left(= \frac{1}{2}\ln\left(\frac{5}{2}\right)\right)$ ***A2*** ***N3***

[3 marks]

Sub-total [10 marks]

Total [22 marks]

3. Part A

(a) Direction vector of $l_1 = \begin{pmatrix} 1 \\ -4 \\ -3 \end{pmatrix}$ *(M1)*

$\Rightarrow$ Equations of line through point A are: $\frac{x}{1} = \frac{y-1}{-4} = \frac{z-2}{-3}$ *A1* *N2*

Note: Accept any correct cartesian form.

[2 marks]

(b) Direction vector of $l_2 = \begin{pmatrix} 1 \\ -4 \\ -3 \end{pmatrix}$ *(M1)*

$\Rightarrow$ vector equation of l_2 is $\boldsymbol{r} = \begin{pmatrix} 3 \\ -8 \\ -11 \end{pmatrix} + \mu \begin{pmatrix} 1 \\ -4 \\ -3 \end{pmatrix}$ *A1* *N2*

Note: Accept only this form but allow $\begin{pmatrix} x \\ y \\ z \end{pmatrix}$ in place of $\boldsymbol{r}$.

[2 marks]

(c) (i) General point on l_1 is $(\lambda, 1-4\lambda, 2-3\lambda)$ *(A1)*

$\overrightarrow{PQ} = \overrightarrow{OQ} - \overrightarrow{OP}$

$= \begin{pmatrix} \lambda \\ 1-4\lambda \\ 2-3\lambda \end{pmatrix} - \begin{pmatrix} 3 \\ -8 \\ -11 \end{pmatrix} = \begin{pmatrix} \lambda-3 \\ 9-4\lambda \\ 13-3\lambda \end{pmatrix}$ *M1A1*

$\Rightarrow \overrightarrow{PQ} \bullet \overrightarrow{l_1} = 0$ *(M1)*

$\Rightarrow \begin{pmatrix} \lambda-3 \\ 9-4\lambda \\ 13-3\lambda \end{pmatrix} \bullet \begin{pmatrix} 1 \\ -4 \\ -3 \end{pmatrix} = 0$ *A1*

$\Rightarrow \lambda - 3 - 36 + 16\lambda - 39 + 9\lambda = 0$

$\Rightarrow 26\lambda = 78 \Rightarrow \lambda = 3$ *A1*

$\Rightarrow Q = (3, -11, -7)$ *A1* *N0*

(ii) $d = \left|\overrightarrow{PQ}\right|$ *(M1)*

$= \sqrt{0+9+16}$ *M1*

$= 5$ *A1* *N1*

[10 marks]

Sub-total [14 marks]

continued ...

Question 3 continued

Part B

(a) $\det = \begin{vmatrix} 1 & 2 & k \\ 1 & 3 & 1 \\ k & 8 & 5 \end{vmatrix} = 1(15-8) - 2(5-k) + k(8-3k)$ ***M1A1***

$\det = -3k^2 + 10k - 3$ ***A1***

Now $\det = 0 \Rightarrow 3k^2 - 10k + 3 = 0$

$\Rightarrow (3k-1)(k-3) = 0$ ***(A1)***

$\Rightarrow k = \frac{1}{3}$ or $k = 3$ ***(A1)***

For unique solution $\det \neq 0 \Rightarrow k \in \mathbb{R}$, $k \neq \frac{1}{3}$ or $k \neq 3$ ***R1*** ***N0***

Note: Allow ***FT*** from previous line for ***R1***.

[6 marks]

(b) $k = \frac{1}{3} \Rightarrow$

$x + 2y + \frac{1}{3}z = 0$ (1)

$x + 3y + z = 3$ (2)

$\frac{1}{3}x + 8y + 5z = 6$ (3)

Attempting to eliminate a variable ***M1***

$3 \times$ equation (1) $-$ equation (2) $\Rightarrow 2x + 3y = -3$ ***A1***

$15 \times$ equation (2) $- 3 \times$ equation (3) $\Rightarrow 14x + 21y = 27 \Rightarrow 2x + 3y = 9$ ***A1***

which is a contradiction so no solution. ***A1*** ***N0***

$k = 3 \Rightarrow$

$x + 2y + 3z = 0$ (1)

$x + 3y + z = 3$ (2)

$3x + 8y + 5z = 6$ (3)

Attempting to eliminate a variable ***M1***

equation (2) $-$ equation (1) $\Rightarrow y - 2z = 3 \Rightarrow z = \frac{y-3}{2}$ ***A1***

$4 \times$ equation (1) $-$ equation (3) $\Rightarrow x + 7z = -6 \Rightarrow z = \frac{x+6}{-7}$ ***A1***

EITHER

Hence there is an infinite number of solutions in the line

$\frac{x+6}{-7} = \frac{y-3}{2} = z$ ***A1*** ***N0***

OR

General solution is $(-6-7\lambda , 3+2\lambda , \lambda)$ ***A1*** ***N0***

Note: Other correct forms are possible.

[8 marks]

Sub-total [14 marks]

Total [28 marks]

4. (a) Using quotient rule *(M1)*

$$f'(x) = \frac{x^3 \times \frac{1}{x} - 3x^2 \ln x}{x^6}$$ ***A1***

$$= \frac{1 - 3\ln x}{x^4}$$ ***A1*** ***N2***

$$f''(x) = \frac{-\frac{3}{x} \times x^4 - 4x^3(1 - 3\ln x)}{x^8}$$ ***M1A1***

$$= \frac{-7 + 12\ln x}{x^5}$$ ***A1*** ***N2***

[6 marks]

(b) (i) For a maximum, $f'(x) = 0$ giving *(M1)*

$$\ln x = \frac{1}{3}$$

$$x = \mathrm{e}^{\frac{1}{3}}$$ ***A1*** ***N2***

EITHER

$$f''\left(\mathrm{e}^{\frac{1}{3}}\right) = \frac{12 \times \frac{1}{3} - 7}{\mathrm{e}^{\frac{5}{3}}} < 0$$ ***M1A1***

$\therefore$ maximum ***AG*** ***N0***

OR

for $x < \mathrm{e}^{\frac{1}{3}}$, $f'(x) > 0$

for $x > \mathrm{e}^{\frac{1}{3}}$, $f'(x) < 0$ ***M1A1***

$\therefore$ maximum ***AG*** ***N0***

(ii) $f''(0) = 0 \Rightarrow \ln(x) = \frac{7}{12}$ ***M1***

$x = \mathrm{e}^{\frac{7}{12}}$ (1.79) ***A1***

$f''(1.5) = -0.281$ ***A1***

$f''(2) = 0.0412$ ***A1***

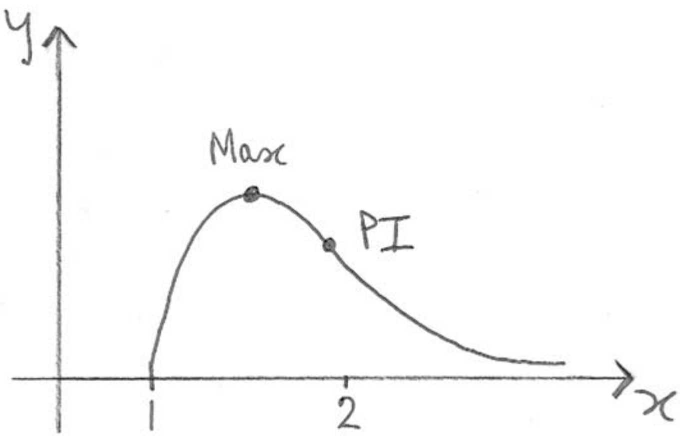
Note: Accept any two sensible values either side of 1.79.

$\therefore$ Change of sign $\Rightarrow$ point of inflexion ***R1***

continued ...

Question 4 continued

(iii)



A1A1

Note:	Award ***A1*** for shape, ***A1*** for marking values which locate the maximum point and point of inflexion correctly.

[11 marks]

(c) Using $V = \int_1^3 \pi y^2 \, dx$ ***(M1)***

$= \int_1^3 \pi \left(\frac{\ln x}{x^3} \right)^2 dx$ ***(A1)***

$= 0.0458$ ***A1*** ***N2***

[3 marks]

(d) Area $A = \int_1^3 \frac{\ln x}{x^3} \, dx$ ***A1***

Using integrating by parts ***(M1)***

$A = \left[-\frac{\ln x}{2x^2} \right]_1^3 + \frac{1}{2} \int_1^3 \frac{1}{x^3} \, dx$ ***A1***

$= -\frac{\ln 3}{18} - \frac{1}{4} \left[\frac{1}{x^2} \right]_1^3$ ***A1A1***

$= -\frac{\ln 3}{18} - \frac{1}{4} \left(\frac{1}{9} - 1 \right) \quad \left(= -\frac{\ln 3}{18} + \frac{2}{9} \right)$ ***A1***

$= \frac{1}{18}(4 - \ln 3)$ ***AG*** ***N0***

[6 marks]

Total [26 marks]

5. (a) $\frac{dy}{d\theta} = -\sin\theta + i\cos\theta$ *A1*

EITHER

$\frac{dy}{d\theta} = i^2 \sin\theta + i\cos\theta$ *A1*

$= i(\cos\theta + i\sin\theta)$ *A1*

$= iy$ *AG* *N0*

OR

$iy = i(\cos\theta + i\sin\theta) \quad (= i\cos\theta + i^2 \sin\theta)$ *A1*

$= i\cos\theta - \sin\theta$ *A1*

$= \frac{dy}{d\theta}$ *AG* *N0*

[3 marks]

(b) $\int \frac{dy}{y} = i\int d\theta$ *M1A1*

$\ln y = i\theta + c$ *A1*

Substituting (0, 1) $\quad 0 = 0 + c \Rightarrow c = 0$ *A1*

$\therefore \ln y = i\theta$ *A1*

$y = e^{i\theta}$ *AG* *N0*

[5 marks]

(c) $\cos n\theta + i\sin n\theta = e^{in\theta}$ *M1*

$= \left(e^{i\theta}\right)^n$ *A1*

$= (\cos\theta + i\sin\theta)^n$ *AG* *N0*

Note: Accept this proof in reverse.

[2 marks]

(d) (i) $\cos 6\theta + i\sin 6\theta = (\cos\theta + i\sin\theta)^6$ *M1*

Expanding rhs using the binomial theorem *M1A1*

$= \cos^6\theta + 6\cos^5\theta i\sin\theta + 15\cos^4\theta(i\sin\theta)^2 + 20\cos^3\theta(i\sin\theta)^3 + 15\cos^2\theta(i\sin\theta)^4 + 6\cos\theta(i\sin\theta)^5 + (i\sin\theta)^6$

Equating imaginary parts *(M1)*

$\sin 6\theta = 6\cos^5\theta\sin\theta - 20\cos^3\theta\sin^3\theta + 6\cos\theta\sin^5\theta$ *A1*

$\frac{\sin 6\theta}{\sin\theta} = 6\cos^5\theta - 20\cos^3\theta(1-\cos^2\theta) + 6\cos\theta(1-\cos^2\theta)^2$ *A1*

$= 32\cos^5\theta - 32\cos^3\theta + 6\cos\theta \quad (a = 32,\ b = -32,\ c = 6)$ *A2* *N0*

(ii) $\lim_{\theta\to 0}\frac{\sin 6\theta}{\sin\theta} = \lim_{\theta\to 0}(32\cos^5\theta - 32\cos^3\theta + 6\cos\theta)$ *M1*

$= 32 - 32 + 6$

$= 6$ *A1* *N0*

[10 marks]

Total [20 marks]