M09/5/MATHL/HP2/ENG/TZ2/XX/M+

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MARKSCHEME

May 2009

MATHEMATICS

ExamsBuddy

Higher Level

Paper 2

Samples to Team Leaders	8 June 2009
Everything (marks, scripts *etc.*) to IB Cardiff	16 June 2009

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.

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.*

- 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.

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:

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

Award ***A1*** for $(2\cos(5x-3))5$, 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.

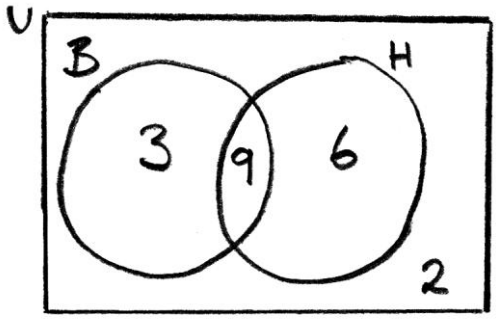
If there is no working shown, and answers are given to the correct two significant figures, apply the ***AP***. However, do **not** accept answers to one significant figure without working.

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.

SECTION A

1. (a)



A1A1

Note: Award ***A1*** for a diagram with two intersecting regions and at least the value of the intersection.

(b) $\frac{9}{20}$ ***A1***

(c) $\frac{9}{12}$ $\left(=\frac{3}{4}\right)$ ***A1***

[4 marks]

2. direction vector for line $=\begin{pmatrix}1\\-1\end{pmatrix}$ or any multiple ***A1***

$\begin{pmatrix}2\sin\theta\\1-\sin\theta\end{pmatrix}\bullet\begin{pmatrix}1\\-1\end{pmatrix}=0$ ***M1***

$2\sin\theta-1+\sin\theta=0$ ***A1***

Note: Allow ***FT*** on candidate's direction vector just for line above only.

$3\sin\theta=1$

$\sin\theta=\frac{1}{3}$ ***A1***

$\theta=0.340$ or 19.5° ***A1***

Note: A coordinate geometry method using perpendicular gradients is acceptable.

[5 marks]

3. (a) $f'(x)=\frac{1}{\sqrt{1-x^2}}-\frac{2x}{\sqrt{1-x^2}}$ $\left(=\frac{1-2x}{\sqrt{1-x^2}}\right)$ ***M1A1A1***

Note: Award ***A1*** for first term,
M1A1 for second term (***M1*** for attempting chain rule).

(b) $f'(x)=0$ ***(M1)***

$x=0.5$, $y=2.26$ or $\frac{\pi}{6}+\sqrt{3}$ $\left(\text{accept } (0.500,\ 2.26)\right)$ ***A1A1*** ***N3***

[6 marks]

4. (a) **EITHER**

translation of $-\frac{1}{2}$ parallel to the *x*-axis

stretch of a scale factor of $\frac{1}{2}$ parallel to the *x*-axis ***A1A1***

OR

stretch of a scale factor of $\frac{1}{2}$ parallel to the *x*-axis

translation of -1 parallel to the *x*-axis ***A1A1***

Note: Accept clear alternative terminologies for either transformation.

(b) **EITHER**

$1.16 < x < 5.71 \cup 6.75 < x \leq 10$ ***A1A1A1A1***

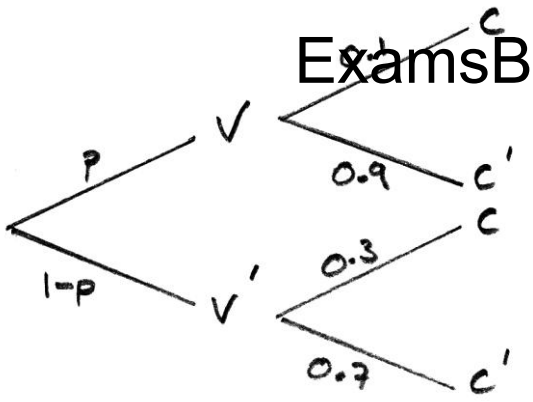
OR

$]1.16, 5.71[\cup]6.75, 10]$ ***A1A1A1A1***

Note: Award ***A1*** for 1 intersection value, ***A1*** for the other 2, ***A1A1*** for the intervals.

[6 marks]

5. (a)



using the law of total probabilities: ***(M1)***

$0.1p + 0.3(1-p) = 0.22$ ***A1***

$0.1p + 0.3 - 0.3p = 0.22$

$0.2p = 0.08$

$p = \frac{0.08}{0.2} = 0.4$

$p = 40\ \%$ (accept 0.4) ***A1***

(b) required probability $= \frac{0.4 \times 0.1}{0.22}$ ***M1***

$= \frac{2}{11}$ (0.182) ***A1***

[5 marks]

6. $\frac{\mathrm{d}v}{\mathrm{d}t} = -\frac{1}{2}v$ ***A1***

$\int \frac{\mathrm{d}v}{v} = \int -\frac{1}{2}\mathrm{d}t$ ***(A1)***

$\ln v = -\frac{1}{2}t + c$ ***(A1)***

$v = \mathrm{e}^{-\frac{1}{2}t+c} \quad \left(= A\mathrm{e}^{-\frac{1}{2}t}\right)$ ***(A1)***

$t = 0$, $v = 40$, so $A = 40$ ***M1***

$v = 40\mathrm{e}^{-\frac{1}{2}t}$ (or equivalent) ***A1***

[6 marks]

7. (a) $\frac{\mathrm{d}y}{\mathrm{d}x} = 24x^2 + 2bx + c$ ***(A1)***

$24x^2 + 2bx + c = 0$ ***(M1)***

$\Delta = (2b)^2 - 96(c)$ ***(A1)***

$4b^2 - 96c > 0$ ***A1***

$b^2 > 24c$ ***AG***

(b) $1 + \frac{1}{4}b + \frac{1}{2}c + d = -12$

$6 + b + c = 0$

$-27 + \frac{9}{4}b - \frac{3}{2}c + d = 20$

$54 - 3b + c = 0$ ***A1A1A1***

Note: Award ***A1*** for each correct equation, up to 3, not necessarily simplified.

$b = 12$, $c = -18$, $d = -7$ ***A1***

[8 marks]

8. EITHER

with no restrictions six people can be seated in $5! = 120$ ways ***A1***
we now count the number of ways in which the two restricted people will be sitting next to each other
call the two restricted people p_1 and p_2
they sit next to each other in two ways ***A1***

the remaining people can then be seated in $4!$ ways ***A1***
the six may be seated (p_1 and p_2 next to each other) in $2 \times 4! = 48$ ways ***M1***
$\therefore$ with p_1 and p_2 not next to each other the number of ways $= 120 - 48 = 72$ ***A1*** ***N3***

[5 marks]

OR

person p_1 seated at table in 1 way ***A1***
p_2 then sits in any of 3 seats (not next to p_1) ***M1A1***
the remaining 4 people can then be seated in $4!$ ways ***A1***
$\therefore$ number ways with p_1 not next to $p_2 = 3 \times 4! = 72$ ways ***A1*** ***N3***

Note: If candidate starts with 6! instead of 5!, potentially leading to an answer of 432, do not penalise.

[5 marks]

9. $\int \sqrt{4 - x^2}\, \mathrm{d}x$

$x = 2\sin\theta$
$\mathrm{d}x = 2\cos\theta\, \mathrm{d}\theta$ ***A1***

$= \int \sqrt{4 - 4\sin^2\theta} \times 2\cos\theta\, \mathrm{d}\theta$ ***M1A1***

$= \int 2\cos\theta \times 2\cos\theta\, \mathrm{d}\theta$

$= 4\int \cos^2\theta\, \mathrm{d}\theta$

now $\int \cos^2\theta\, \mathrm{d}\theta$

$= \int \left(\frac{1}{2}\cos 2\theta + \frac{1}{2}\right) \mathrm{d}\theta$ ***M1A1***

$= \left(\frac{\sin 2\theta}{4} + \frac{1}{2}\theta\right)$ ***A1***

so original integral

$= \sin 2\theta + 2\theta$
$= 2\sin\theta\cos\theta + 2\theta$
$= \left(2 \times \frac{x}{2} \times \frac{\sqrt{4 - x^2}}{2}\right) + 2\arcsin\left(\frac{x}{2}\right)$
$= \frac{x\sqrt{4 - x^2}}{2} + 2\arcsin\left(\frac{x}{2}\right) + C$ ***A1A1***

Note: Do not penalise omission of *C*.

$\left(A = \frac{1}{2},\ B = 2\right)$

[8 marks]

10. (a) let $\hat{\text{HPQ}} = \theta$

$\tan\theta = \frac{h}{40}$

$\sec^2\theta \frac{\text{d}\theta}{\text{d}t} = \frac{1}{40}\frac{\text{d}h}{\text{d}t}$ ***M1***

$\frac{\text{d}\theta}{\text{d}t} = \frac{1}{4\sec^2\theta}$ ***(A1)***

$= \frac{16}{4\times 25}$ $\left(\sec\theta = \frac{5}{4} \text{ or } \theta = 0.6435\right)$ ***A1***

$= 0.16$ radians per second ***AG***

(b) $x^2 = h^2 + 1600$, where $\text{PH} = x$

$2x\frac{\text{d}x}{\text{d}t} = 2h\frac{\text{d}h}{\text{d}t}$ ***M1***

$\frac{\text{d}x}{\text{d}t} = \frac{h}{x}\times 10$ ***A1***

$= \frac{10h}{\sqrt{h^2+1600}}$ ***(A1)***

$h = 30$, $\frac{\text{d}x}{\text{d}t} = 6 \text{ m s}^{-1}$ ***A1***

Note: Accept solutions that begin $x = 40\sec\theta$ or use $h = 10t$.

[7 marks]

SECTION B

11. (a) $X \sim \mathrm{N}(998, 2.5^2)$ ***M1***

$\mathrm{P}(X > 1000) = 0.212$ ***AG***

[1 mark]

(b) $X \sim \mathrm{B}(5, 0.2119...)$

evidence of binomial ***(M1)***

$\mathrm{P}(X = 3) = \binom{5}{3}(0.2119...)^3(0.7881...)^2 = 0.0591$ (accept 0.0592) ***(M1)A1***

[3 marks]

(c) $\mathrm{P}(X \geq 1) = 1 - \mathrm{P}(X = 0)$ ***(M1)***

$1 - (0.7881...)^n > 0.99$

$(0.7881...)^n < 0.01$ ***A1***

Note: Award ***A1*** for line 2 or line 3 or equivalent.

$n > 19.3$ ***(A1)***

minimum number of bottles required is 20 ***A1N2***

[4 marks]

(d) $\frac{996 - \mu}{\sigma} = -1.1998$ (accept -1.2) ***M1A1***

$\frac{1000 - \mu}{\sigma} = 0.3999$ (accept 0.4) ***M1A1***

$\mu = 999(ml), \sigma = 2.50(ml)$ ***A1A1***

[6 marks]

(e) (i) $\frac{\mathrm{e}^{-m}m^2}{2!} = \frac{\mathrm{e}^{-m}m^3}{3!} + \frac{\mathrm{e}^{-m}m^4}{4!}$ ***M1A1***

$\frac{m^2}{2} = \frac{m^3}{6} + \frac{m^4}{24}$

$12m^2 - 4m^3 - m^4 = 0$ ***(A1)***

$m = -6, 0, 2$

$\Rightarrow m = 2$ ***A1N2***

(ii) $\mathrm{P}(X > 2) = 1 - \mathrm{P}(X \leq 2)$ ***(M1)***

$= 1 - \mathrm{P}(X = 0) - \mathrm{P}(X = 1) - \mathrm{P}(X = 2)$

$= 1 - \mathrm{e}^{-2} - 2\mathrm{e}^{-2} - \frac{2^2\mathrm{e}^{-2}}{2!}$

$= 0.323$ ***A1***

[6 marks]

Total [20 marks]

12. (a) $PQ = 50$ and non-intersecting ***R1***

[1 mark]

(b) a construction QT (where T is on the radius MP), parallel to MN, so that $Q\hat{T}M = 90^\circ$ (angle between tangent and radius $= 90^\circ$) ***M1***

lengths 50, $x - 10$ and angle θ marked on a diagram, or equivalent ***R1***

Note: Other construction lines are possible.

[2 marks]

(c) (i) $MN = \sqrt{50^2 - (x-10)^2}$ ***A1***

(ii) maximum for MN occurs when $x = 10$ ***A1***

[2 marks]

(d) (i) $\alpha = 2\pi - 2\theta$ ***M1***

$= 2\pi - 2\arccos\left(\frac{x-10}{50}\right)$ ***A1***

(ii) $\beta = 2\pi - \alpha \ (= 2\theta)$ ***A1***

$= 2\left(\cos^{-1}\left(\frac{x-10}{50}\right)\right)$ ***A1***

[4 marks]

(e) (i) $b(x) = x\alpha + 10\beta + 2\sqrt{50^2 - (x-10)^2}$ ***A1A1A1***

$= x\left(2\pi - 2\left(\cos^{-1}\left(\frac{x-10}{50}\right)\right)\right) + 20\left(\cos^{-1}\left(\frac{x-10}{50}\right)\right) + 2\sqrt{50^2 - (x-10)^2}$

M1A1

(ii) maximum value of perimeter $= 276$ ***A2***

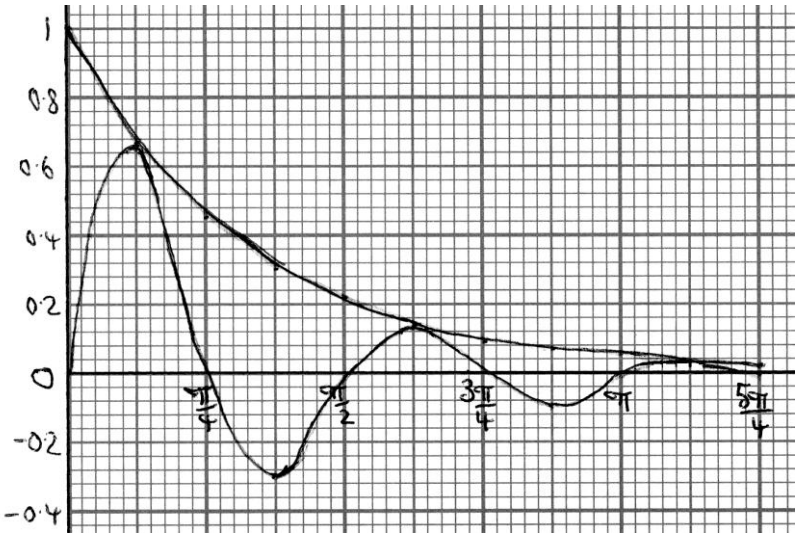
(iii) perimeter of 200 cm $b(x) = 200$ ***(M1)***

when $x = 21.2$ ***A1***

[9 marks]

Total [18 marks]

13. (a)



A3

Note:	Award ***A1*** for each correct **shape**, ***A1*** for correct relative position.

[3 marks]

(b) $e^{-x}\sin(4x) = 0$ ***(M1)***

$\sin(4x) = 0$ ***A1***

$4x = 0,\ \pi,\ 2\pi,\ 3\pi,\ 4\pi,\ 5\pi$ ***A1***

$x = 0, \frac{\pi}{4}, \frac{2\pi}{4}, \frac{3\pi}{4}, \frac{4\pi}{4}, \frac{5\pi}{4}$ ***AG***

[3 marks]

(c) $e^{-x} = e^{-x}\sin(4x)$ or reference to graph

$\sin 4x = 1$ ***M1***

$4x = \frac{\pi}{2}, \frac{5\pi}{2}, \frac{9\pi}{2}$ ***A1***

$x = \frac{\pi}{8}, \frac{5\pi}{8}, \frac{9\pi}{8}$ ***A1*** ***N3***

[3 marks]

(d) (i) $y = e^{-x}\sin 4x$

$\frac{dy}{dx} = -e^{-x}\sin 4x + 4e^{-x}\cos 4x$ ***M1A1***

$y = e^{-x}$

$\frac{dy}{dx} = -e^{-x}$ ***A1***

verifying equality of gradients at one point ***R1***

verifying at the other two ***R1***

(ii) since $\frac{dy}{dx} \neq 0$ at these points they cannot be local maxima ***R1***

[6 marks]

continued ...

Question 13 continued

(e) (i) maximum when $y' = 4e^{-x}\cos 4x - e^{-x}\sin 4x = 0$ ***M1***

$x = \frac{\arctan(4)}{4}, \frac{\arctan(4)+\pi}{4}, \frac{\arctan(4)+2\pi}{4}, \ldots$

maxima occur at

$x = \frac{\arctan(4)}{4}, \frac{\arctan(4)+2\pi}{4}, \frac{\arctan(4)+4\pi}{4}$ ***A1***

so $y_1 = e^{-\frac{1}{4}(\arctan(4))}\sin(\arctan(4))$ $(= 0.696)$ ***A1***

$y_2 = e^{-\frac{1}{4}(\arctan(4)+2\pi)}\sin(\arctan(4)+2\pi)$ ***A1***

$\left(= e^{-\frac{1}{4}(\arctan(4)+2\pi)}\sin(\arctan(4)) = 0.145\right)$

$y_3 = e^{-\frac{1}{4}(\arctan(4)+4\pi)}\sin(\arctan(4)+4\pi)$ ***A1***

$\left(= e^{-\frac{1}{4}(\arctan(4)+4\pi)}\sin(\arctan(4)) = 0.0301\right)$ ***N3***

(ii) for finding and comparing $\frac{y_3}{y_2}$ and $\frac{y_2}{y_1}$ ***M1***

$r = e^{-\frac{\pi}{2}}$ ***A1***

Note: Exact values must be used to gain the ***M1*** and the ***A1***.

[7 marks]

Total [22 marks]