MEET THE EXAMINERS (Dec 2016)

Mary Papp (mary.a.papp@hotmail.com)
The number of students who sat for the 2015 examination was 15 634. Overall responses were quite satisfactory with fewer candidates in the very low range.

The format and structure of the 2015 Maths Methods 1 examination was very similar to previous years and responses given by students indicated that the questions were highly accessible. **Students are encouraged to view the examination as an opportunity to demonstrate their knowledge and skills**

Areas of strength included:

- use of the chain rule (Question 1)
- sketching the graphs of a cubic polynomial function (Question 4b.)
- solving equations involving circular functions (Question 5b.)
- solving equations involving logarithms (Question 7a.)
- basic probability (Question 8a.).

Areas of weakness included:

- antidifferentiation involving negative fractional powers (Question 3)
- average value, solving equations involving exponential functions (Question 4c.)
- solving exponential equations involving negative indices (Question 7b.)
- conditional probability (Questions 6b. and 9bii.).
Other things that assessors felt a need to comment upon:

(AND WHAT IS OF REAL CONCERN TO TEACHERS!!!)

1) Failure to ANSWER THE SPECIFIC QUESTION

- answer all parts and only that which is asked for

- is there a specified format for the answer (decimal places)

- are there restrictions of which to be wary (restricted domain)
  Can’t have logs or square roots that are negative
  Probabilities that fall outside [0,1]
  A negative area or height

- instructions that must be obeyed
  “HENCE”, “SHOW THAT”, “USE…….”
  LABEL…… with their coordinates, asymptotes with their equation….
2) Errors with simple arithmetic calculations, especially those involving fractions or decimals, or in manipulating/simplifying algebraic expressions. This was particularly prevalent in Questions 1, 2, 3, 6b., 7a., 8a. and 9a.

The classics that are seemingly becoming more prevalent

\[
\frac{0.34}{0.5} = 0.17
\]

\[(x+3)^2 = x^2 + 9\]

\[x(x-2) = 15 \text{ so } x = 15 \text{ or } 17\]

\[
\frac{1 - p}{5} \cdot \frac{5}{5} = -\frac{p}{2p} = -\frac{1}{2}
\]

\[
\log_e (6-x) - \log_e (x+4) = \frac{\log_e (6-x)}{\log_e (x+4)}
\]

\[
\frac{1}{\sqrt{x}} = -x^2
\]
3) Correct mathematical notation

(near enough is not good enough)

\[ \frac{dy}{dx} \]

Pi that look like \( x \),

Logarithm notations: \( \log_e x \) appeared as \( \text{logex or loge}^x \)

Brackets: \( \log_e x + 1 \neq \log_e (x + 1) \)

\[ x^2 + 3(\sin x) \neq (x^2 + 3)\sin x \]

Domain/Range \( [0, \infty) \neq (0, \infty) \)

\[ k^{-1} = \sqrt{e - 1} \text{ in lieu of } k^{-1}(x) = \sqrt{e - 1} \]
A few important tips

Candidates needed to realise that their responses need to be explicit and clear. Assessors can assess only what appears in front of them and are unable to interpret what is not written down. (Work down the page, one = per line)

Assessors are not permitted to think for the candidate (simplify the answer)

If a question is worth more than one mark, methodology must be given. A correct answer must come from correct working !!)

Do not rely on consequential marks

A diagram is often perfectly acceptable (probability)

Graphs (hairy, cross asymptotes, any endpoints)

Legibility. (of figures/digits, faint pencil working, a clutter of processes within one line of working)

Do not overwork the problem !

Must know the exact trig ratios in all 4 quadrants
A significant number could not solve a quadratic equation by the most efficient method and it is concerning that many could not even recognise an equation that could be transformed into standard quadratic form, leading to a routine solution.
Question 1

a. Let \( y = (5x + 1)^7 \)
Find \( \frac{dy}{dx} \).

\[
\frac{dy}{dx} = 7 \times 5(5x + 1)^6
= 35(5x + 1)^6
\]

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b. Let \( f(x) = \frac{\log_e(x)}{x^2} \)

i. Find \( f'(x) \).

\[
f'(x) = \frac{\left(1 \times x^2\right) - 2x \log_e(x)}{x^4}
= \frac{x - 2x \log_e(x)}{x^4}
= \frac{1 - 2 \log_e(x)}{x^3}
\]

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<td>18</td>
<td>72</td>
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ii. Evaluate \( f'(1) \).

\[
f'(1) = \frac{1 + 2 \log_e(1)}{1}
= 1 \text{ since } \log_e(1) = 0.
\]

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Question 2

Let \( f'(x) = 1 - \frac{3}{x} \), where \( x \neq 0 \). Given that \( f(e) = -2 \), find \( f(x) \).

\[
\begin{align*}
  f(x) &= x - 3 \log_e(|x|) + c \\
  f(e) &= e - 3 \log_e(e) + c = -2 \\
  e - 3 + c &= -2 \\
  c &= 1 - e \\
  f(x) &= x - 3 \log_e(x) + 1 - e
\end{align*}
\]

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<td>14</td>
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Points to note:

* Quite a few good solutions were seen. It is disturbing to see those who did not recognise the ‘log’ aspect and increased the index to 0 or even 1. Fortunately, this was not a high number.

* There were errors in evaluation of the arbitrary constant. Some omitted the constant but substituted the given values anyway to get something nonsensical such as \( e = 1 \).

Question 3 (2 marks)

Evaluate \( \int_1^4 \left( \frac{1}{\sqrt{x}} \right) \, dx \).

\[
\begin{align*}
  4 &= \int x^{-\frac{1}{2}} \, dx = [2x^{\frac{1}{2}}] \\
  1 &= 2 \times 2 - 2 \times 1 \\
  &= 2
\end{align*}
\]

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Question 4 (6 marks)
Consider the function \( f : [-3, 2] \rightarrow R, \ f(x) = \frac{1}{2}(x^3 + 3x^2 - 4). \)

a. Find the coordinates of the stationary points of the function.

\[
f'(x) = \frac{3}{2}x(x + 2) = 0
\]

\( x = 0 \) or \( x = -2 \)

\( f(0) = -2, \ f(-2) = 0 \)

Coordinates \((0, -2), (-2, 0)\)

Marks | 0 | 1 | 2 | Mean
--- | --- | --- | --- | ---
% | 14 | 24 | 62 | 1.47

The rule for \( f \) can also be expressed as \( f(x) = \frac{1}{2}(x-1)(x+2)^2. \)

b. On the axes below, sketch the graph of \( f \), clearly indicating axis intercepts and turning points. Label the end points with their coordinates. 2 marks

There were plenty of excellent graphs and very few that had wonky curvature. It is especially pleasing that many candidates respected the restricted domain, though errors occurred with the calculation or the placement of the endpoints.

Some did not relate to part (a)

| Marks | 0 | 1 | 2 | Mean
--- | --- | --- | --- | ---
% | 40 | 19 | 41 | 1.00
c. Find the average value of \( f \) over the interval \( 0 \leq x \leq 2 \).

Average Value = \( \frac{1}{2 - 0} \int_0^2 f(x) \, dx = \frac{1}{2 - 0} \int_0^2 \frac{1}{2} (x^3 + 3x^2 - 4) \, dx \)

\[
= \frac{1}{2} \times \frac{1}{2} \left[ \frac{x^4}{4} + x^3 - 4x \right]_0^2 \\
= \frac{1}{4} [(4 + 8 - 8) - 0] \\
= 1
\]

Points to note

* Some very good solutions were given and it was good to see that the formula was quoted despite it not being on the formula sheet.

* Confusing average value with average rate of change, thus finding a gradient.

* Some broke the interval into \([0,1]\) and \([1,2]\) making the solution more cumbersome and some of these placed a negative sign before the first interval.

Others thought that the area was required.
Question 5 (3 marks)
On any given day, the depth of water in a river is modelled by the function

\[ h(t) = 14 + 8 \sin \left( \frac{\pi t}{12} \right), \quad 0 \leq t \leq 24 \]

where \( h \) is the depth of water, in metres, and \( t \) is the time, in hours, after 6 am.

a. Find the minimum depth of the water in the river.

**Minimum depth = 14 – 8 = 6 metres.**

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* Quite well done although answers such as 22 and -6 appeared. Were these candidates confused by down being positive? Others found the maximum “height”.

* The candidates who used calculus to obtaining a minimum value found it a costly method with respect to time and tended to make careless errors in the differentiation.

b. Find the values of \( t \) for which \( h(t) = 10 \).

\[ 14 + 8 \sin \left( \frac{\pi t}{12} \right) = 10 \]

\[ \sin \left( \frac{\pi t}{12} \right) = -\frac{1}{2} \]

\[ \frac{\pi t}{12} = \frac{7\pi}{6}, \quad \frac{11\pi}{6} \]

\[ t = 14, \ 22 \]

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* This question was well handled. Most candidates set up an equation which when solved would yield the two correct answers for the restricted domain.

Some candidates did not recognise the “base angle” of \( \frac{\pi}{6} \).
**Question 6 (3 marks)**

Let the random variable \(X\) be normally distributed with mean 2.5 and standard deviation 0.3.

Let \(Z\) be the standard normal random variable, such that \(Z \sim N(0, 1)\).

**a.** Find \(b\) such that \(\Pr(X > 3.1) = \Pr(Z < b)\). 

\[
\Pr\left(Z > \frac{3.1 - 2.5}{0.3}\right) = \Pr(Z < b)
\]

\[
\Pr(Z > 2) = \Pr(Z < b) \\
b = -2.
\]

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* Those candidates who drew a diagram of a “normal” curve with relevant areas shaded seem to fair the best.
* Fairly well done. 2 appeared sometimes as an answer while others failed to answer the question explicitly.
* The answer of 1.9 which was just as frequent is two standard deviations below the mean of \(X\).

**b.** Using the fact that, correct to two decimal places, \(\Pr(Z < -1) = 0.16\), find \(\Pr(X < 2.8 \mid X > 2.5)\).

Write the answer correct to two decimal places. 

\[
\Pr\left(X < \mu + 1\sigma \mid X > \mu\right) = \Pr\left(0 < Z < 1\right) \div 2 \\
= 2(0.5 - (0.16)) = 0.68
\]

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<td>22</td>
<td>36</td>
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* Quite a lot of candidates could not handle the conditional aspect failing to recognise that

\[
\Pr\left(X < 2.8 \mid X > 2.5\right) = \frac{\Pr(2.5 < X < 2.8)}{\Pr(X > 2.5)}.
\]

* Many others failed to see that \(\Pr(X < 2.5) = 0.5\).
* Disturbingly, others left the answer as the quotient of two decimals unsimplified.
* Some demonstrated poor arithmetical skills.

E.g., \(0.34 \div 0.50 = 0.17\) was not uncommon.

* Those working correctly often used a diagram such as the one above.

* Whilst \(\frac{17}{25}\) was accepted as being correct to two decimal places **on this occasion**, one may wonder whether these candidates **re-read** the question on completion of their solution.
**Question 7 (5 marks)**

a. Solve \( \log_2(6 - x) - \log_2(4 - x) = 2 \) for \( x \), where \( x < 4 \).

\[
\log_2 \left( \frac{6 - x}{4 - x} \right) = 2
\]

\[
\frac{6 - x}{4 - x} = 4
\]

\[
6 - x = 16 - 4x
\]

\[
x = \frac{10}{3}
\]

* Candidates still perform poorly with log functions.
* Some tried to do two steps in one with \( \frac{6 - x}{4 - x} = 2 \) instead of \( 2^2 \).

Also, \( 3x = 10 \Rightarrow x = \frac{3}{10} \) was too common.

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<td>19</td>
<td>65</td>
<td>1.49</td>
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b. Solve \( 3e^t = 5 + 8e^{-t} \) for \( t \).

\[
3e^t = 5 + 8e^{-t}
\]

\[
3e^{2t} - 5e^t - 8 = 0
\]

\[
(e^t + 1)(3e^t - 8) = 0
\]

\[
e^t \neq -1, \quad e^t = \frac{8}{3} \Rightarrow t = \log_e \left( \frac{8}{3} \right)
\]

* The first move should have been to make a substitution for \( e^t \). Even if this were done, forming a quadratic equation posed many difficulties. Those who successfully formed a quadratic equation often solved it by using the formula rather than using factorisation.

*manipulating \( e^{-t} \)
Question 8 (3 marks)
For events \( A \) and \( B \) from a sample space, \( \Pr(A \mid B) = \frac{3}{4} \) and \( \Pr(B) = \frac{1}{3} \).

a. Calculate \( \Pr(A \cap B) \).

\[
\Pr(A \cap B) = \Pr(A \mid B) \times \Pr(B) = \frac{3}{4} \times \frac{1}{3} = \frac{1}{4}
\]

1 mark

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<td>87</td>
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b. Calculate \( \Pr(A' \cap B) \), where \( A' \) denotes the complement of \( A \).

\[
\Pr(A' \cap B) = \Pr(B) - \Pr(A \cap B) = \frac{1}{3} - \frac{1}{12} = \frac{1}{4}
\]

1 mark

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<td>59</td>
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* A Karnaugh map was most useful for formulating a solution.

* Some poor manipulation of fractions was evident in this question.

c. If events \( A \) and \( B \) are independent, calculate \( \Pr(A \cup B) \).

If \( A \) and \( B \) independent, then \( \Pr(A \mid B) = \Pr(A) \).

\[
\Pr(A \cup B) = \Pr(A) + \Pr(B) - \Pr(A \cap B) = \frac{3}{4} + \frac{1}{3} - \frac{1}{6} = \frac{5}{6}
\]

1 mark

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* Confusion with mutually exclusive

* Final answers well outside the interval \([0,1]\). This should have rung alarm bells!
Question 9 (4 marks)

An egg marketing company buys its eggs from farm $A$ and farm $B$. Let $p$ be the proportion of eggs that the company buys from farm $A$. The rest of the company's eggs come from farm $B$. Each day, the eggs from both farms are taken to the company's warehouse.
Assume that $\frac{3}{5}$ of all eggs from farm $A$ have white eggshells and $\frac{1}{5}$ of all eggs from farm $B$ have white eggshells.

a. An egg is selected at random from the set of all eggs at the warehouse.

Find, in terms of $p$, the probability that the egg has a white eggshell. 

$$Pr(W) = Pr(A) \times Pr(W|A) + Pr(B) \times Pr(W|B)$$

$$Pr(W) = p \times \frac{3}{5} + (1-p) \times \frac{1}{5}$$

$$= \frac{2p + 1}{5}$$

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<td>53</td>
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* It is of considerable concern that numerical answers were given here [& in 9b] despite the question requiring an answer in terms of $p$. This should have been a straightforward tree diagram solution or an application of the Law of Total Probability.

* A significant number left their answer unsimplified in the form of the sum of two products.

* Those who failed to simplify their expressions had problems in completing 9b.

* Some candidates made good use of a tree diagram in completing their answers.
b. Another egg is selected at random from the set of all eggs at the warehouse.

i. Given that the egg has a white eggshell, find, in terms of $p$, the probability that it came from farm $B$. 

$$
Pr(B | W) = \frac{Pr(B \cap W)}{Pr(W)} = \frac{\frac{1-p}{5}}{\frac{2p+1}{5}} = \frac{1-p}{2p+1}
$$

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<td>26</td>
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* A reasonable number understood the conditional nature of the question but could not apply the concept correctly. Many used the answer to Q.9a in the denominator. Getting the numerator correct was another problem, even though it was used as part of Q.9a.

* Too many gave an answer that contained [sums of] decimals on numerator and denominator without any attempt to simplify.
ii. If the probability that this egg came from farm $B$ is 0.3, find the value of $p$. 

\[ \Pr(B|W) = 0.3 = \frac{1-p}{2p+1} \]

\[ 0.6p + 0.3 = 1 - p \]

\[ p = \frac{7}{16} \]

*Too many took the easy way out giving 0.7 as the answer, ignoring the conditional nature of the situation; that is, the clue of “this egg” was overlooked.*

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Question 10 (7 marks)
The diagram below shows a point, \(T\), on a circle. The circle has radius 2 and centre at the point \(C\) with coordinates \((2, 0)\). The angle \(ECT\) is \(\theta\), where \(0 < \theta \leq \frac{\pi}{2}\).

The diagram also shows the tangent to the circle at \(T\). This tangent is perpendicular to \(CT\) and intersects the \(x\)-axis at point \(X\) and the \(y\)-axis at point \(Y\).

a. Find the coordinates of \(T\) in terms of \(\theta\). 

\[(2 + 2\cos(\theta), 2\sin(\theta))\]

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* Not well done. Of those who had a germ of any idea, the addition of 2 was missing from the \(x\)-co-ordinate.

b. Find the gradient of the tangent to the circle at \(T\) in terms of \(\theta\). 

\[m_{CT} = \tan(\theta)\]

\[m_{XY} = -\frac{1}{\tan(\theta)} \text{ or equivalent}\]

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Poor response. Some gave the gradient of the normal \(CT\); others thought that \(T\) had its \(x\)-co-ordinate as 3. [Diagrams are not drawn to scale!]

* Some candidates included the variables of \(b\) or \(d\) in their final answer.
* \(-\cot(\theta)\) was acceptable.
Candidates are never penalised for having correct knowledge outside the curriculum.
c. The equation of the tangent to the circle at $T$ can be expressed as
\[ \cos(\theta)x + \sin(\theta)y = 2 + 2\cos(\theta) \]

i. Point $B$, with coordinates $(2, b)$, is on the line segment $XY$.

Find $b$ in terms of $\theta$. 

\[ b \sin(\theta) + 2 \cos(\theta) = 2 + 2 \cos(\theta) \]
\[ b = \frac{2}{\sin(\theta)} \]

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It was pleasing to note the note that a significant number of candidates who had no success with parts a. and b. managed to attain full marks in this section. The most efficient method was to substitute the co-ordinates of the relevant points into the given equation and then transpose to obtain the variable requested.

* Curiously, some left answers not fully simplified even though simplification was obvious such as cancellation of factor 2.

ii. Point $D$, with coordinates $(4, d)$, is on the line segment $XY$.

Find $d$ in terms of $\theta$. 

\[ d \sin(\theta) + 4 \cos(\theta) = 2 + 2 \cos(\theta) \]
\[ d = \frac{2 - 2 \cos(\theta)}{\sin(\theta)} \]

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Simplification errors

b or d floating
d. Consider the trapezium $CEDB$ with parallel sides of length $b$ and $d$.

Find the value of $\theta$ for which the area of the trapezium $CEDB$ is a minimum. Also find the minimum value of the area.  

$$A(\theta) = \frac{b + d}{2} \times 2 = \frac{2}{\sin(\theta)} + \frac{2 - 2\cos(\theta)}{\sin(\theta)} = \frac{4 - 2\cos(\theta)}{\sin(\theta)}$$

$$A'(\theta) = \frac{2 - 4\cos(\theta)}{\sin^2(\theta)} = 0$$

$$\cos(\theta) = \frac{1}{2}$$

$$\theta = \frac{\pi}{3}$$

$$A\left(\frac{\pi}{3}\right) = \frac{4 - 2\cos\left(\frac{\pi}{3}\right)}{\sin\left(\frac{\pi}{3}\right)} = \frac{3}{\frac{\sqrt{3}}{2}} = \frac{6}{\sqrt{3}} = 2\sqrt{3}$$

Many candidates did not attempt this question suggesting time management issues.

Candidates found this question difficult as the first step required an expression for the area of a trapezium in terms of only $\theta$. Others were thwarted by the derivative of their area expression.

Some fine solutions were seen with accurate calculus and accurate algebra. Those who simplified $en$ route fared best.

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