Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Wednesday 6 October 2021 – Afternoon

Time 2 hours

Paper reference **9MA0/01**

Mathematics

Advanced
PAPER 1: Pure Mathematics 1

You must have:
Mathematical Formulae and Statistical Tables (Green), calculator

Total Marks

Candidates may use any calculator allowed by Pearson regulations. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Inexact answers should be given to three significant figures unless otherwise stated.

Information

- A booklet 'Mathematical Formulae and Statistical Tables' is provided.
- There are 15 questions in this question paper. The total mark for this paper is 100.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over

P 6 8 7 3 1 A 0 1 5 2

Pearson

1. $$f(x) = ax^3 + 10x^2 - 3ax - 4$$

Given that $(x - 1)$ is a factor of $f(x)$, find the value of the constant a.

You must make your method clear.

(3)

By the factor theorem, as $(x-1)$ is a factor then

$$f(1) = 0.$$

So

$$f(1) = a(1)^3 + 10(1)^2 - 3a(1) - 4 = 0$$

$$a + 10 - 3a - 4 = 0$$

$$6 - 2a = 0$$

$$6 = 2a$$

$$a = 3.$$

Question 1 continued

(Total for Question 1 is 3 marks)

2. Given that

$$f(x) = x^2 - 4x + 5 \qquad x \in \mathbb{R}$$

(a) express $f(x)$ in the form $(x + a)^2 + b$ where a and b are integers to be found.

(2)

The curve with equation $y = f(x)$

- meets the y-axis at the point P
- has a minimum turning point at the point Q

(b) Write down

(i) the coordinates of P

(ii) the coordinates of Q

(2)

a) $f(x) = (x-2)^2 - 4 + 5$

$f(x) = (x-2)^2 + \underline{1}$.

bi) y meets the y-axis when $x=0$.

$y = f(0) = 5$.

$P = (0,5)$.

bii) As we have used completing the square in part a, we know that ~~there~~ will be minimum turning point when the square is 0. So

$f(2) = (2-2)^2 + 1 = 1$.

Minimum $Q = (2,1)$

Question 2 continued

(Total for Question 2 is 4 marks)

3. The sequence $u_1, u_2, u_3, \ldots$ is defined by

$$u_{n+1} = k - \frac{24}{u_n} \qquad u_1 = 2$$

where k is an integer.

Given that $u_1 + 2u_2 + u_3 = 0$

(a) show that

$$3k^2 - 58k + 240 = 0$$

(3)

(b) Find the value of k, giving a reason for your answer.

(2)

(c) Find the value of u_3

(1)

a) $u_1 = 2, \qquad u_2 = k - \frac{24}{2} = k - 12.$

$u_3 = k - \frac{24}{k-12}. \qquad 2u_2 = 2k - 24.$

Subsituting into $u_1 + 2u_2 + u_3 = 0.$

$2 + 2k - 24 + k - \frac{24}{k-12} = 0.$

$3k - 22 - \frac{24}{k-12} = 0$

$\times(k-12) \qquad \times(k-12)$

$3k(k-12) - 22(k-12) - 24 = 0 \times (k-12)$

$3k^2 - 36k - 22k + 264 - 24 = 0$

$\Rightarrow 3k^2 - 58k + 240 = 0 \quad \square$

b) Factorised: $(3k-40)(k-6) = 0$

$k = \frac{40}{3}$ or $k = 6.$

However $k \neq 40/3$ as it is an integer, hence $k = 6.$

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Question 3 continued

c) Subsituting $k=6$ into $u_3 = k - \frac{24}{k-12}$.

$u_3 = 6 - \frac{24}{6-12} = 6 - \frac{24}{-6} = 6+4 = 10.$

$u_3 = 10.$

(Total for Question 3 is 6 marks)

4. The curve with equation $y = f(x)$ where

$$f(x) = x^2 + \ln(2x^2 - 4x + 5)$$

has a single turning point at $x = \alpha$

(a) Show that α is a solution of the equation

$$2x^3 - 4x^2 + 7x - 2 = 0$$

(4)

The iterative formula

$$x_{n+1} = \frac{1}{7}(2 + 4x_n^2 - 2x_n^3)$$

is used to find an approximate value for α.

Starting with $x_1 = 0.3$

(b) calculate, giving each answer to 4 decimal places,

(i) the value of x_2

(ii) the value of x_4

(3)

Using a suitable interval and a suitable function that should be stated,

(c) show that α is 0.341 to 3 decimal places.

(2)

a) $y = f(x) = x^2 + \ln(2x^2 - 4x + 5)$

$$\frac{dy}{dx} = 2x + \frac{1}{2x^2-4x+5} \times \frac{d}{dx}(2x^2 - 4x + 5)$$

(by chain rule).

$$\frac{dy}{dx} = 2x + \frac{4x-4}{2x^2-4x+5}$$

So the turning point is when $dy/dx = 0$.

$$2x + \frac{4x-4}{2x^2-4x+5} = 0 \qquad \times(2x^2-4x+5)$$

$$2x(2x^2-4x+5) + 4x - 4 = 0 \times (2x^2-4x+5)$$

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Question 4 continued

$4x^3 - 8x^2 + 10x + 4x - 4 = 0$

$4x^3 - 8x^2 + 14x - 4 = 0 \quad \div 2$

$2x^3 - 4x^2 + 7x - 2 = 0. \quad \square$

bi) $x_2 = \frac{1}{7} \times (2 + 4(0.3)^2 - 2 \times (0.3)^3)$

$x_2 = 0.3294$ (4dp).

bii) $x_3 = 0.3375$ (4dp).

$x_4 = 0.3398$ (4dp).

c) $f'(x) = 2x + \frac{4x-4}{2x^2-4x+5}$

Let $h(x) = 2x^3 - 4x^2 + 7x - 2$.
As we have already shown $h(x) = 0$ when $f(x)$ has a turning point.
So $h(\alpha) = 0$.

$h(0.3405) = -0.001305...$
$h(0.3415) = 0.003663...$

As both $f'(x)$ and $h(x)$ are continuous and there is a change of sign between $x = 0.3405$ and $x = 0.3415$ then the solution $\alpha = 0.341$ to 3 decimal place.

Turn over

Question 4 continued

Question 4 continued

(Total for Question 4 is 9 marks)

5. **In this question you should show all stages of your working.**

Solutions relying entirely on calculator technology are not acceptable.

A company made a profit of £20 000 in its first year of trading, Year 1

A model for future trading predicts that the yearly profit will increase by 8% each year, so that the yearly profits will form a geometric sequence.

According to the model,

(a) show that the profit for Year 3 will be £23 328 **(1)**

(b) find the first year when the yearly profit will exceed £65 000 **(3)**

(c) find the total profit for the first 20 years of trading, giving your answer to the nearest £1000 **(2)**

a) Year 3 profits $= 20\,000 \times 1.08^2$

$= £23,328.$

b) The first year n, such that

$20,000 \times 1.08^{n-1} > 65,000$

$\Rightarrow \quad 1.08^{n-1} > 13/4$

$\Rightarrow \quad \ln(1.08^{n-1}) > \ln(13/4)$

$\Rightarrow \quad (n-1)\ln(1.08) > \ln(3.25)$

$n-1 > \dfrac{\ln(3.25)}{\ln(1.08)}$

$n > \dfrac{\ln(3.25)}{\ln(1.08)} + 1 = 16.3149\ldots$

So the first year would be year 17.

Question 5 continued

c) Using the formula for sum of a geometric sequence:

$$S_{20} = \frac{20\,000 \times (1 - 1.08^{20})}{1 - 1.08}$$

$$S_{20} = 915239.286.$$

Profit of the first 20 years: £915,000 to the nearest £1000.

(Total for Question 5 is 6 marks)

6.

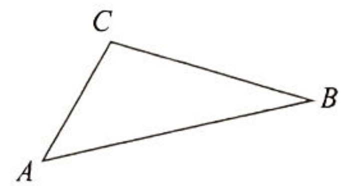

Figure 1

Figure 1 shows a sketch of triangle ABC.

Given that

- $\overrightarrow{AB} = -3\mathbf{i} - 4\mathbf{j} - 5\mathbf{k}$
- $\overrightarrow{BC} = \mathbf{i} + \mathbf{j} + 4\mathbf{k}$

(a) find $\overrightarrow{AC}$

(2)

(b) show that $\cos ABC = \dfrac{9}{10}$

(3)

a) $\overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC} = -3\underline{i} - 4\underline{j} - 5\underline{k} + \underline{i} + \underline{j} + 4k$

$\overrightarrow{AC} = -2\underline{i} - 3\underline{j} - \underline{k}$

b) Cosine rule:

$|AB|^2 + |BC|^2 - 2|AB||BC| \cdot \cos ABC = |AC|^2$

$|AB| = \sqrt{(-3)^2 + (-4)^2 + (-5)^2} = 5\sqrt{2}, \ |AB|^2 = 50.$

$|BC| = \sqrt{1^2 + 1^2 + 4^2} = 3\sqrt{2}, \ |BC|^2 = 18$

$|AC| = \sqrt{(-2)^2 + (-3)^2 + (-1)^2} = \sqrt{14}, \ |AC|^2 = 14.$

$\Rightarrow 14 = 50 + 18 - 2 \times 5\sqrt{2} \times 3\sqrt{2} \times \cos ABC$

$14 = 68 - 60 \cos ABC$

$60 \cos ABC = 54$

$\cos ABC = 54/60 \Rightarrow \cos ABC = \frac{9}{10}$ $\square$

Question 6 continued

P 6 8 7 3 1 A 0 1 5 5 2

Question 6 continued

Question 6 continued

(Total for Question 6 is 5 marks)

7. The circle C has equation

$$x^2 + y^2 - 10x + 4y + 11 = 0$$

(a) Find

(i) the coordinates of the centre of C,

(ii) the exact radius of C, giving your answer as a simplified surd.

(4)

The line l has equation $y = 3x + k$ where k is a constant.

Given that l is a tangent to C,

(b) find the possible values of k, giving your answers as simplified surds.

(5)

ai) $x^2 - 10x + y^2 + 4y + 11 = 0$

Completing the square:

$(x-5)^2 - 25 + (y+2)^2 - 4 + 11 = 0$

$(x-5)^2 + (y+2)^2 = 18$.

The centre is $(5, -2)$.

ii) Radius $= \sqrt{18} = 3\sqrt{2}$.

b) $y = 3x + k$, subsitute into equation for C.

$(x-5)^2 + (3x+k+2)^2 = 18$

Expand: $x^2 - 10x + 25 + 9x^2 + 3kx + 6x + 3kx + k^2 + 2k + 6x + 2k + 4 = 18$.

$\Rightarrow 10x^2 + 2x + 6kx + k^2 + 4k + 11 = 0$

$10x^2 + (6k+2)x + (k^2 + 4k + 11) = 0$

This quadratic must have $b^2 - 4ac = 0$ as a tangent intersects a circle only once.

Question 7 continued

$b = 6k + 2$
$c = k^2 + 4k + 11$
$a = 10.$

$(6k+2)^2 - 4 \times 10 \times (k^2 + 4k + 11) = 0$

$36k^2 + 24k + 4 - 40k^2 - 160k - 440 = 0.$

$-4k^2 - 136k - 436 = 0.$
$4k^2 + 136k + 436 = 0.$

Using quadratic formula:

$$k = \frac{-136 \pm \sqrt{136^2 - 4 \times 4 \times 436}}{2 \times 4}$$

$$k = \frac{-136 \pm 48\sqrt{5}}{8}$$

$k = -17 \pm 6\sqrt{5}.$

Question 7 continued

Question 7 continued

(Total for Question 7 is 9 marks)

8. A scientist is studying the growth of two different populations of bacteria.

The number of bacteria, N, in the **first** population is modelled by the equation

$$N = Ae^{kt} \qquad t \geqslant 0$$

where A and k are positive constants and t is the time in hours from the start of the study.

Given that

- there were 1000 bacteria in this population at the start of the study
- it took exactly 5 hours from the start of the study for this population to double

(a) find a complete equation for the model.

(4)

(b) Hence find the rate of increase in the number of bacteria in this population exactly 8 hours from the start of the study. Give your answer to 2 significant figures.

(2)

The number of bacteria, M, in the **second** population is modelled by the equation

$$M = 500e^{1.4kt} \qquad t \geqslant 0$$

where k has the value found in part (a) and t is the time in hours from the start of the study.

Given that T hours after the start of the study, the number of bacteria in the two different populations was the same,

(c) find the value of T.

(3)

a) When $t=0$ $\quad e^{kt}=1 \quad N=A=1000$.
When $t=5$ $\quad e^{5k}=2$.

$5k=\ln(2)$
$k=\frac{1}{5}\ln(2)$.

$N=1000\,e^{(\frac{1}{5}\ln(2))t}$.

b) $\frac{dN}{dt}=1000\times\left(\frac{1}{5}\ln(2)\right)\times e^{(\frac{1}{5}\ln(2))t}$

$\left(\frac{dN}{dt}\right)_{t=8}=1000\times\left(\frac{1}{5}(\ln(2))\right)\times e^{(\frac{1}{5}\ln(2))\times 8}$

$=420$ (to 2 significant figures).

Question 8 continued

c) $500e^{1.4(\ln(2)/5)T} = 1000e^{\left(\frac{\ln(2)}{5}\right)T}$

$e^{1.4kT} = 2e^{kT}$

$\frac{e^{1.4kT}}{e^{kT}} = 2$

$e^{1.4kT-kT} = 2$

$1.4\left(\frac{1}{5}\ln(2)\right)T - \left(\frac{1}{5}\ln(2)\right)T = \ln(2)$

$0.4 \times \left(\frac{1}{5}\ln(2)\right)T = \ln(2)$

$0.08\ln(2)T = \ln(2)$

$0.08T = 1.$

$T = 12.5$ hours.

P 6 8 7 3 1 A 0 2 3 5 2

Question 8 continued

Question 8 continued

(Total for Question 8 is 9 marks)

9.

$$f(x) = \frac{50x^2 + 38x + 9}{(5x+2)^2(1-2x)} \qquad x \neq -\frac{2}{5} \quad x \neq \frac{1}{2}$$

Given that f(x) can be expressed in the form

$$\frac{A}{5x+2} + \frac{B}{(5x+2)^2} + \frac{C}{1-2x}$$

where A, B and C are constants

(a) (i) find the value of B and the value of C

(ii) show that $A = 0$

(4)

(b) (i) Use binomial expansions to show that, in ascending powers of x

$$f(x) = p + qx + rx^2 + \ldots$$

where p, q and r are simplified fractions to be found.

(ii) Find the range of values of x for which this expansion is valid.

(7)

ai)

$$\frac{A}{5x+2} + \frac{B}{(5x+2)^2} + \frac{C}{1-2x} \equiv \frac{A(5x+2)(1-2x) + B(1-2x) + C(5x+2)^2}{(1-2x)(5x+2)^2}$$

$$50x^2 + 38x + 9 \equiv A(5x+2)(1-2x) + B(1-2x) + C(5x+2)^2$$

If $x = 0.5$

$$50(0.5)^2 + 38(0.5) + 9 = A \times 0 + B \times 0 + C(5(0.5)+2)^2$$

$\Rightarrow 40.5 = C \times 20.25$

$\Rightarrow C = 2$

If $x = -0.4$

$$50(-0.4)^2 + 38(-0.4) + 9 = A \times 0 + B(1 - 2 \times (-0.4)) + C \times 0$$

$\Rightarrow 1.8 = B \times 1.8 \Rightarrow B = 1$

Question 9 continued

ii) If $x=0$

$50\times0+38\times0+9=A(2)(1)+1\times(1)+2\times(2)^2$

$\Rightarrow 9=2A+1+8$

$9=2A+9 \Rightarrow A=0.$

bi) $\frac{1}{(5x+2)^2}=(5x+2)^{-2}=2^{-2}\left(1+\frac{5}{2}x\right)^{-2}$

$\left(1+\frac{5}{2}x\right)^{-2}=1-2\left(\frac{5}{2}x\right)+\frac{-2(-3)}{2}\left(\frac{5}{2}x\right)^2+\ldots$

$=1-5x+\frac{75}{4}x^2+\ldots$

$2^{-2}\left(1+\frac{5}{2}x\right)^{-2}=\frac{1}{4}-\frac{5x}{4}+\frac{75}{16}x^2+\ldots$

$\frac{2}{1-2x}=2(1-2x)^{-1}$

$(1-2x)^{-1}=1+2x+\frac{(-1)(-2)}{2}(-2x)^2+\ldots$

$=1+2x+4x^2+\ldots$

$2(1-2x)^{-1}=2+4x+8x^2+\ldots$

$f(x)=\frac{1}{(5x+2)^2}+\frac{2}{1-2x}$ *

$f(x)=\frac{1}{4}-\frac{5}{4}x+\frac{75}{16}x^2+\ldots+2+4x+8x^2+\ldots$

$f(x)=\frac{9}{4}+\frac{11}{4}x+\frac{203}{16}x^2+\ldots$

Question 9 continued

b ii) $\left|\frac{5}{2}x\right| < 1$ and $|2x| < 1$

$\Rightarrow |x| < \frac{2}{5}$ is the range of values this expansion is valid for.

Question 9 continued

(Total for Question 9 is 11 marks)

10. **In this question you should show all stages of your working.**

Solutions relying entirely on calculator technology are not acceptable.

(a) Given that $1 + \cos 2\theta + \sin 2\theta \neq 0$ prove that

$$\frac{1 - \cos 2\theta + \sin 2\theta}{1 + \cos 2\theta + \sin 2\theta} \equiv \tan\theta$$

(4)

(b) Hence solve, for $0 < x < 180°$

$$\frac{1 - \cos 4x + \sin 4x}{1 + \cos 4x + \sin 4x} = 3\sin 2x$$

giving your answers to one decimal place where appropriate.

(4)

a) By the double angle formula

$\cos 2\theta = 1 - 2\sin^2\theta$
$\cos 2\theta = 2\cos^2\theta - 1$
$\sin 2\theta = 2\sin\theta\cos\theta.$

$LHS = \dfrac{1 - \cos 2\theta + \sin 2\theta}{1 + \cos 2\theta + \sin 2\theta}$ Subsituting in the double-angle formulae

$LHS = \dfrac{1 - (1 - 2\sin^2\theta) + 2\sin\theta\cos\theta}{1 + (2\cos^2\theta - 1) + 2\sin\theta\cos\theta}$

$LHS = \dfrac{1 - 1 + 2\sin^2\theta + 2\sin\theta\cos\theta}{1 + 2\cos^2\theta - 1 + 2\sin\theta\cos\theta}$

$LHS = \dfrac{2\sin^2\theta + 2\sin\theta\cos\theta}{2\cos^2\theta + 2\sin\theta\cos\theta}$

$LHS = \dfrac{2\sin\theta(\sin\theta + \cos\theta)}{2\cos\theta(\sin\theta + \cos\theta)}$ (cancelling out)

$LHS = \dfrac{\sin\theta}{\cos\theta} = \tan\theta = RHS$ □

Question 10 continued

b) Using $2x = \theta$ then we may use our identity proven in part (a).

$$\frac{1-\cos 4x+\sin 4x}{1+\cos 4x+\sin 4x} = \tan 2x$$

Solve $\tan(2x) = 3\sin 2x$

$$\frac{\sin 2x}{\cos 2x} = 3\sin 2x$$

$$\sin 2x = 3\sin 2x \cos 2x$$

$$3\sin 2x\cos 2x - \sin 2x = 0$$

$$\sin 2x(3\cos 2x - 1) = 0.$$

Solutions:

$\sin 2x = 0$ and $3\cos 2x - 1 = 0$.

$x = 90°$ and $\cos 2x = 1/3$.

$x = 35.3°$ and $144.7°$ (to 1 decimal place).

Question 10 continued

Question 10 continued

(Total for Question 10 is 8 marks)

11.

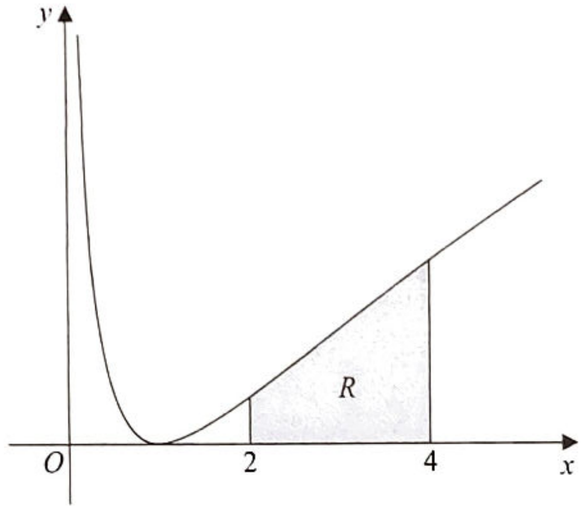

Figure 2

Figure 2 shows a sketch of part of the curve with equation

$$y = (\ln x)^2 \qquad x > 0$$

The finite region R, shown shaded in Figure 2, is bounded by the curve, the line with equation $x = 2$, the x-axis and the line with equation $x = 4$

The table below shows corresponding values of x and y, with the values of y given to 4 decimal places.

x	2	2.5	3	3.5	4
y	0.4805	0.8396	1.2069	1.5694	1.9218

(a) Use the trapezium rule, with all the values of y in the table, to obtain an estimate for the area of R, giving your answer to 3 significant figures.

(3)

(b) Use algebraic integration to find the exact area of R, giving your answer in the form

$$y = a(\ln 2)^2 + b\ln 2 + c$$

where a, b and c are integers to be found.

(5)

a) $h = 0.5$

$A \approx 0.5 \times \frac{1}{2} \times \left(0.4805 + 1.9218 + 2 \times (0.8396 + 1.2069 + 1.5694)\right)$

$A \approx \underline{2.41}$

b) We apply integration by parts

$$\int v \frac{du}{dx}\, dx = uv - \int u \frac{dv}{dx}\, dx.$$

Let $v = (\ln x)^2$ and $\frac{du}{dx} = 1$, $u = x$.

$\frac{dv}{dx} = \frac{2\ln(x)}{x}$ (by chain rule)

Subsituting these into integration by parts

$$\int (\ln(x))^2 dx = x(\ln x)^2 - \int x \times \frac{2\ln(x)}{x}\, dx$$

$$= x(\ln x)^2 - 2\int \ln(x)\, dx.$$

To find $\int \ln(x)\, dx$ we use the integration by parts method again.

Let $v = \ln x$ and $\frac{du}{dx} = 1$, $u = x$.

$\frac{dv}{dx} = \frac{1}{x}$ so

$$\int \ln(x)\, dx = x\ln(x) - \int x \cdot \frac{1}{x}\, dx$$

$$= x\ln(x) - x (+c)$$

$$\Rightarrow \int (\ln(x))^2 dx = x(\ln x)^2 - 2\left(x\ln(x) - x\right) + C$$

$$= x(\ln x)^2 - 2x\ln(x) + 2x + C.$$

$$\int_2^4 (\ln x)^2 dx = \left[x(\ln x)^2 - 2x\ln(x) + 2x\right]_2^4$$

Question 11 continued

$$\int_2^4 (\ln x)^2 \, dx$$

$$= \left(4(\ln 4)^2 - 2\times 4\times \ln(4) + 2\times 4\right)$$

$$- \left(2(\ln 2)^2 - 2\times 2\ln(2) + 2\times 2\right)$$

$$(\ln(4) = 2\ln(2))$$

$$= \left(4\times(2\ln 2)^2 - 8\times 2\ln(2) + 8\right)$$

$$- \left(2(\ln 2)^2 - 4\ln(2) + 4\right)$$

$$= 16(\ln 2)^2 - 16\ln(2) + 8 - 2(\ln(2))^2 + 4\ln(2) - 4$$

$$\int_2^4 (\ln x)^2 \, dx = 14(\ln 2)^2 - 12\ln(2) + 4$$

Question 11 continued

(Total for Question 11 is 8 marks)

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12.

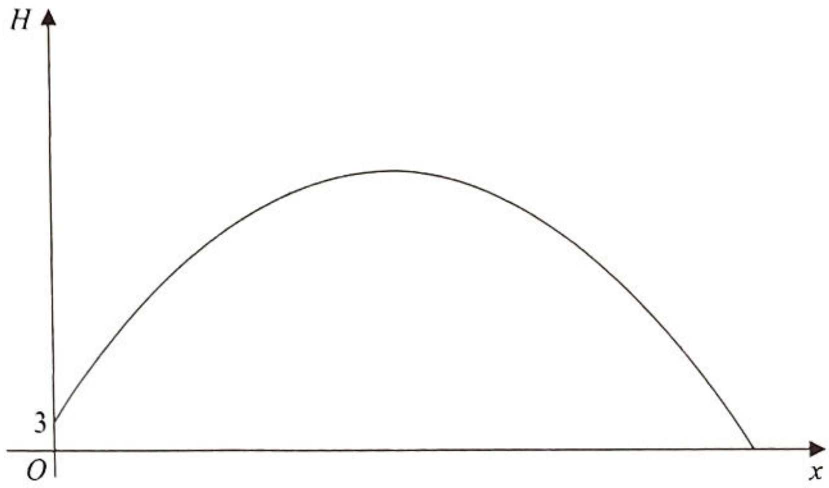

Figure 3

Figure 3 is a graph of the trajectory of a golf ball after the ball has been hit until it first hits the ground.

The vertical height, H metres, of the ball above the ground has been plotted against the horizontal distance travelled, x metres, measured from where the ball was hit.

The ball is modelled as a particle travelling in a vertical plane above horizontal ground.

Given that the ball

- is hit from a point on the top of a platform of vertical height 3 m above the ground
- reaches its maximum vertical height after travelling a horizontal distance of 90 m
- is at a vertical height of 27 m above the ground after travelling a horizontal distance of 120 m

Given also that H is modelled as a **quadratic** function in x

(a) find H in terms of x

(5)

(b) Hence find, according to the model,

(i) the maximum vertical height of the ball above the ground,

(ii) the horizontal distance travelled by the ball, from when it was hit to when it first hits the ground, giving your answer to the nearest metre.

(3)

(c) The possible effects of wind or air resistance are two limitations of the model. Give one other limitation of this model.

(1)

a)

$H = ax^2 + bx + c$

Given that $H = 3$ when $x = 0$, $c = 3$.

Question 12 continued

$$\frac{dH}{dx} = 2ax + b$$

and the turning point (the maximum) occours when $x = 90$ so

$$180a + b = 0$$

We also know that when $x = 120$, $H = 27$ so

$$27 = 120^2 a + 120b + 3$$
$$14400a + 120b = 24$$
$$\Rightarrow 600a + 5b = 1.$$

and we can subsitute in $b = -180a$.

$$600a + 5 \times (-180a) = 1$$
$$600a - 900a = 1$$
$$-300a = 1$$
$$a = \frac{-1}{300}.$$

$$b = -180 \times \left(-\frac{1}{300}\right)$$

$$b = 3/5.$$

$$\Rightarrow H = -\frac{1}{300}x^2 + \frac{3}{5}x + 3.$$

bi) Maximum vertical height when $x = 90$m.

$$H = -\frac{(90)^2}{300} + \frac{3}{5} \times 90 + 3$$

$$H = 30\text{m}$$

b ii) The horizontadistance when $H=0$.

$$-\frac{1}{300}x^2+\frac{3}{5}x+3=0$$

$$-x^2+180x+900=0.$$

Using quadratic formula

$$x=\frac{-180\pm\sqrt{180^2-4\times-1\times900}}{2\times-1}$$

$x=-4.868\ldots$ or

$x=184.868\ldots$

The horizontal distance is 185m (nearest metre).

c) The ball is not a particle and has dimensions and so should not be modelled as one.

Question 12 continued

(Total for Question 12 is 9 marks)

13. A curve C has parametric equations

$$x = \frac{t^2 + 5}{t^2 + 1} \qquad y = \frac{4t}{t^2 + 1} \qquad t \in \mathbb{R}$$

Show that all points on C satisfy

$$(x - 3)^2 + y^2 = 4$$

(3)

$$(x-3)^2 = \left(\frac{t^2+5}{t^2+1} - 3\right)^2 = \left(\frac{t^2+5-3(t^2+1)}{t^2+1}\right)^2$$

$$(x-3)^2 = \left(\frac{2-2t^2}{t^2+1}\right)^2 = \frac{(2-2t^2)^2}{(t^2+1)^2}$$

$$y^2 = \left(\frac{4t}{t^2+1}\right)^2 = \frac{16t^2}{(t^2+1)^2}$$

$$(x-3)^2 + y^2 = \frac{(2-2t^2)^2}{(t^2+1)^2} + \frac{16t^2}{(t^2+1)^2}$$

$$= \frac{4-8t^2+4t^4}{(t^2+1)^2} + \frac{16t^2}{(t^2+1)^2}$$

$$= \frac{4t^4+8t^2+4}{(t^2+1)^2}$$

$$= \frac{4(t^4+2t^2+1)}{(t^2+1)^2}$$

$$= \frac{4(t^2+1)^2}{(t^2+1)^2}$$

$$(x-3)^2 + y^2 = 4 \quad \square$$

Question 13 continued

(Total for Question 13 is 3 marks)

14. Given that

$$y = \frac{x-4}{2+\sqrt{x}} \qquad x > 0$$

show that

$$\frac{dy}{dx} = \frac{1}{A\sqrt{x}} \qquad x > 0$$

where A is a constant to be found.

(4)

Quotient Rule:

$$\frac{d}{dx}\left(\frac{f(x)}{g(x)}\right) = \frac{g(x)f'(x) - f(x)g'(x)}{(g(x))^2}$$

Let $f(x) = x-4$, $f'(x) = 1$
and $g(x) = 2+\sqrt{x}$, $g'(x) = \frac{1}{2}x^{-1/2} = \frac{1}{2\sqrt{x}}$.

So as $y = \frac{x-4}{2+\sqrt{x}}$

$$\frac{dy}{dx} = \frac{(2+\sqrt{x})\times 1 - (x-4)(\frac{1}{2}x^{-1/2})}{(2+\sqrt{x})^2}$$

$$\frac{dy}{dx} = \frac{2+\sqrt{x} - 0.5x^{1/2} + 2x^{-1/2}}{(2+\sqrt{x})^2}$$

$$\frac{dy}{dx} = \frac{2+\frac{1}{2}\sqrt{x} + 2(\sqrt{x})^{-1}}{(2+\sqrt{x})^2} \times \frac{2\sqrt{x}}{2\sqrt{x}}$$

$$\frac{dy}{dx} = \frac{4\sqrt{x} + x + 4}{2\sqrt{x}(2+\sqrt{x})^2} = \frac{(2+\sqrt{x})^2}{2\sqrt{x}(2+\sqrt{x})^2}$$

$$\frac{dy}{dx} = \frac{1}{2\sqrt{x}} \quad \square$$

Question 14 continued

Question 14 continued

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

Question 14 continued

(Total for Question 14 is 4 marks)

15. (i) Use proof by exhaustion to show that for $n \in \mathbb{N}, n \leqslant 4$

$$(n+1)^3 > 3^n$$

(2)

(ii) Given that $m^3 + 5$ is odd, use proof by contradiction to show, using algebra, that m is even.

(4)

i) The cases are $n = 1, 2, 3, 4$.

For $n=1$: $(1+1)^3 = 2^3 = 8$, $3^1 = 3$.

$\Rightarrow 8 > 3$, true for $n=1$.

For $n=2$: $(2+1)^3 = 3^3 = 27$, $3^2 = 9$

$\Rightarrow 27 > 9$, true for $n=2$.

For $n=3$: $(3+1)^3 = 4^3 = 64$, $3^3 = 27$

$\Rightarrow 64 > 27$, true for $n=3$.

For $n=4$: $(4+1)^3 = 5^3 = 125$, $3^4 = 81$

$\Rightarrow 125 > 81$, true for all $n \in \mathbb{N}$ where $n \leq 4 \Rightarrow (n+1)^3 > 3^n$.

ii) Assume for contradiction that m is odd.

Therefore $m = 2p+1$ for some integer p.

As $m^3 + 5$ is odd so must be $(2p+1)^3 + 5$.

$(2p+1)^3 + 5 = (2p+1)(4p^2 + 4p + 1) + 5$

$= 8p^3 + 12p^2 + 6p + 6$

Question 15 continued

~~$(2p+1)^3+5 = 2(4p^3+12p^2+6$~~

$(2p+1)^3+5 = 2(4p^3+6p^2+3p+3)$

Hence contradiction as $(4p^3+6p^2+3p+3)\times 2$ cannot be ~~odd~~ even

$\Rightarrow$ m cannot be odd and must be even.

Question 15 continued

P 6 8 7 3 1 A 0 5 0 5 2

Question 15 continued

Question 15 continued

(Total for Question 15 is 6 marks)

TOTAL FOR PAPER IS 100 MARKS