Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number ☐☐☐☐☐ Candidate Number ☐☐☐☐

Pearson Edexcel Level 3 GCE

Time 2 hours

Paper reference **9MA0/02**

Mathematics

Advanced

PAPER 2: Pure Mathematics 2

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 16 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 ▶

Pearson

1. **In this question you must show all stages of your working.**

Solutions relying entirely on calculator technology are not acceptable.

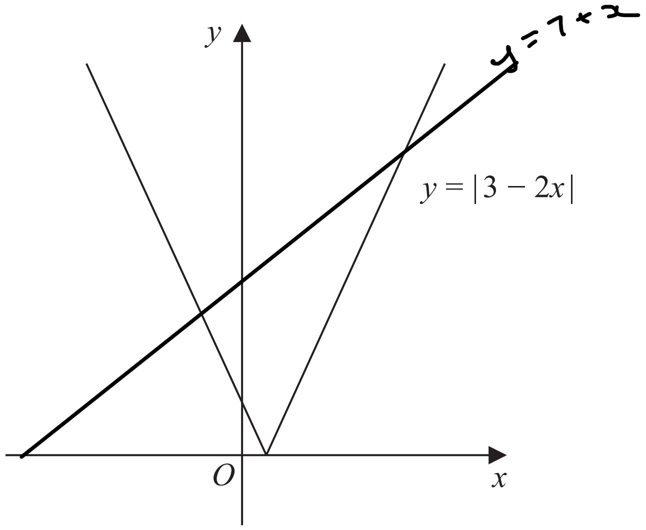


Figure 1

Figure 1 shows a sketch of the graph with equation $y = |3 - 2x|$

Solve

$$|3 - 2x| = 7 + x$$

(4)

$3 - 2x = 7 + x$

$-4 = 3x$

$\frac{-4}{3} = x$

$-(3 - 2x) = 7 + x$

$-3 + 2x = 7 + x$

$x = 10$

Question 1 continued

(Total for Question 1 is 4 marks)

2. (a) Sketch the curve with equation

$$y = 4^x$$

stating any points of intersection with the coordinate axes.

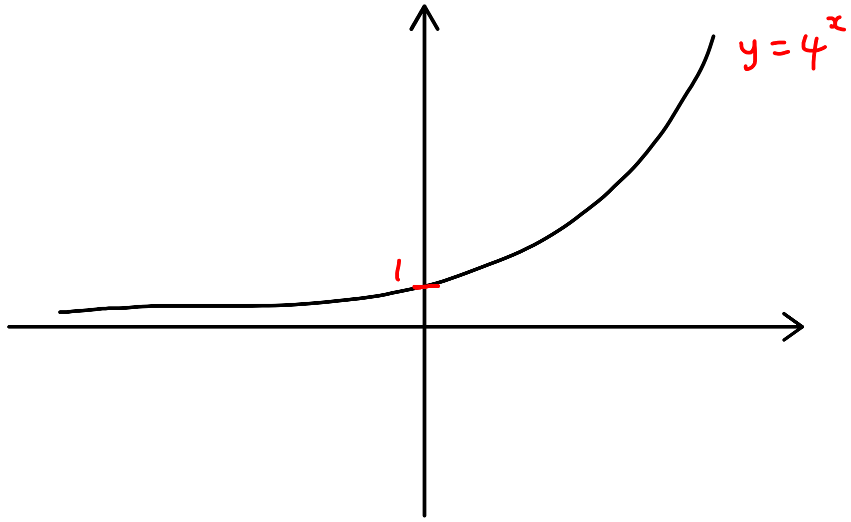
(2)

(b) Solve

$$4^x = 100$$

giving your answer to 2 decimal places.

(2)



Question 2 continued

b/ $4^{x} = 100$

$\ln 4^{x} = \ln 100$

$x \ln 4 = \ln 100$

$x = \dfrac{\ln 100}{\ln 4}$

$= \underline{\underline{3.32}}$

(Total for Question 2 is 4 marks)

3. A sequence of terms $a_1, a_2, a_3, \dots$ is defined by

$$a_1 = 3$$
$$a_{n+1} = 8 - a_n$$

(a) (i) Show that this sequence is periodic.

(ii) State the order of this periodic sequence.

(2)

(b) Find the value of

$$\sum_{n=1}^{85} a_n$$

(2)

a i) $a_1 = 3$

$a_2 = 8 - 3 = 5$

$a_3 = 8 - 5 = 3$

$a_4 = 8 - 3 = 5$

$3, 5, 3, 5, 3, 5 \dots$

ii) 2

b) $\sum_{n=1}^{85} a_n = 3 + 5 + 3 + 5 \dots + 3 + 5 + 3$

$= 42(3 + 5) + 3$

$= \underline{\underline{339}}$

Question 3 continued

(Total for Question 3 is 4 marks)

4. Given that

$$y = 2x^2$$

use differentiation from first principles to show that

$$\frac{dy}{dx} = 4x$$

(3)

$$f'(x) = \lim_{h \to 0} \frac{f(x+h) - f(x)}{h}$$

$$\frac{dy}{dx} = \lim_{h \to 0} \frac{2(x+h)^2 - 2x^2}{h}$$

$$= \lim_{h \to 0} \frac{2(x^2 + 2xh + h^2) - 2x^2}{h}$$

$$= \lim_{h \to 0} \frac{2x^2 + 4xh + 2h^2 - 2x^2}{h}$$

$$= \lim_{h \to 0} \frac{4xh + 2h^2}{h}$$

$$= \lim_{h \to 0} 4x + 2h$$

As $h \to 0$ $2h \to 0$

$$\therefore \frac{dy}{dx} = 4x$$

Question 4 continued

(Total for Question 4 is 3 marks)

5. The table below shows corresponding values of x and y for $y = \log_3 2x$

The values of y are given to 2 decimal places as appropriate.

x	3	4.5	6	7.5	9
y	1.63	2	2.26	2.46	2.63

(a) Using the trapezium rule with all the values of y in the table, find an estimate for

$$\int_3^9 \log_3 2x \, dx$$

(3)

Using your answer to part (a) and making your method clear, estimate

(b) (i) $\int_3^9 \log_3 (2x)^{10} \, dx$

(ii) $\int_3^9 \log_3 18x \, dx$

(3)

a/ $1.5\left(\frac{1.63}{2} + 2 + 2.26 + 2.46 + \frac{2.63}{2}\right)$

$= \underline{\underline{13.3}}$

b i/ $\log_3 (2x)^{10} = 10 \log_3 (2x)$

$10 \times 13.3 = \underline{\underline{133}}$

ii/ $\log_3 18x = \log_3 2x + \log_3 9$

$= \log_3 2x + 2$

$13.3 + 2 \times 6$ $9 - 3 = 6$

$= \underline{\underline{25.3}}$

Question 5 continued

(Total for Question 5 is 6 marks)

6.

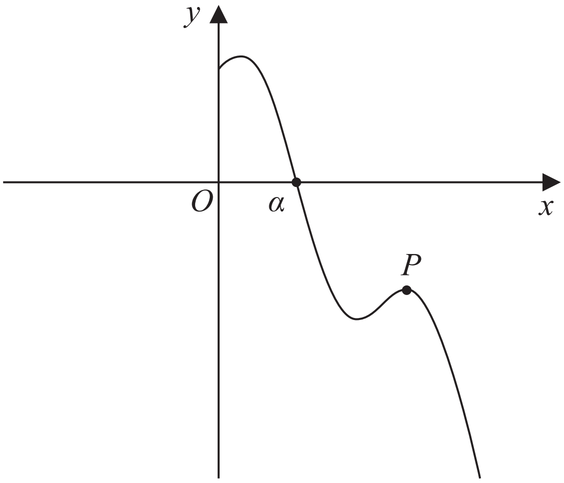


Figure 2

Figure 2 shows a sketch of part of the curve with equation $y = \mathrm{f}(x)$ where

$$\mathrm{f}(x) = 8\sin\left(\frac{1}{2}x\right) - 3x + 9 \qquad x > 0$$

and x is measured in radians.

The point P, shown in Figure 2, is a local maximum point on the curve.

Using calculus and the sketch in Figure 2,

(a) find the x coordinate of P, giving your answer to 3 significant figures.

(4)

The curve crosses the x-axis at $x = \alpha$, as shown in Figure 2.

Given that, to 3 decimal places, $\mathrm{f}(4) = 4.274$ and $\mathrm{f}(5) = -1.212$

(b) explain why α must lie in the interval $[4, 5]$

(1)

(c) Taking $x_0 = 5$ as a first approximation to α, apply the Newton-Raphson method once to $\mathrm{f}(x)$ to obtain a second approximation to α.

Show your method and give your answer to 3 significant figures.

(2)

a/ Maximum where $f'(x) = 0$

$$f'(x) = 4\cos(\tfrac{1}{2}x) - 3$$

$$4\cos(\tfrac{1}{2}x) - 3 = 0$$

Question 6 continued

$$\cos\left(\frac{1}{2}x\right) = \frac{3}{4}$$

$$\frac{1}{2}x = 0.723, 5.56, 7.01$$

P is the 3rd stationary point.

$$\underline{\underline{x = 14.0}}$$

b/ There is a change of sign and it is a continuous function.

c/

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

$$x_0 = 5$$

$$x_1 = 5 - \frac{8\sin\left(\frac{5}{2}\right) - 3(5) + 9}{4\cos\left(\frac{5}{2}\right) - 3}$$

$$= \underline{\underline{4.80}}$$

Question 6 continued

Question 6 continued

(Total for Question 6 is 7 marks)

7. (a) Find the first four terms, in ascending powers of x, of the binomial expansion of

$$\sqrt{4-9x}$$

writing each term in simplest form.

(4)

A student uses this expansion with $x = \frac{1}{9}$ to find an approximation for $\sqrt{3}$

Using the answer to part (a) and without doing any calculations,

(b) state whether this approximation will be an overestimate or an underestimate of $\sqrt{3}$ giving a brief reason for your answer.

(1)

a/ $(4-9x)^{\frac{1}{2}}$

$4^{\frac{1}{2}}\left(1-\frac{9}{4}x\right)^{\frac{1}{2}}$

$2\left(1-\frac{9}{4}x\right)^{\frac{1}{2}}$

$2\left(1+\frac{1}{2}\left(\frac{-9}{4}x\right)+\frac{\frac{1}{2}\left(\frac{-1}{2}\right)}{2}\left(-\frac{9}{4}x\right)^{2}+\frac{\frac{1}{2}\left(\frac{-1}{2}\right)\left(\frac{-3}{2}\right)}{6}\left(\frac{-9}{4}x\right)^{3}\right)$

$2\left(1-\frac{9}{8}x-\frac{81}{128}x^{2}-\frac{729}{1024}x^{3}\right)$

$2-\frac{9}{4}x-\frac{81}{64}x^{2}-\frac{729}{512}x^{3}$

b/ It will be an overestimate as all following terms will be negative.

Question 7 continued

(Total for Question 7 is 5 marks)

8. **In this question you must show all stages of your working.**

Solutions relying on calculator technology are not acceptable.

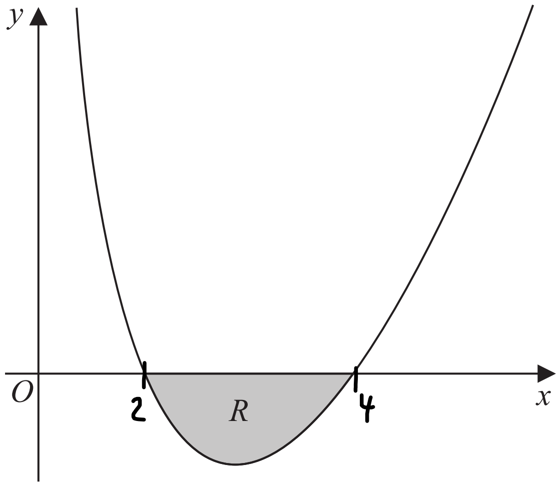


Figure 3

Figure 3 shows a sketch of part of a curve with equation

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

The region R, shown shaded in Figure 3, is bounded by the curve and the x-axis.

Find the exact area of R, writing your answer in the form $a\sqrt{2} + b$, where a and b are constants to be found.

(6)

Crosses x when $y = 0$

$$0 = \frac{(x-2)(x-4)}{4\sqrt{x}}$$

$$0 = (x-2)(x-4)$$

$$x = 2 \qquad x = 4$$

$$y = \frac{(x-2)(x-4)}{4x^{\frac{1}{2}}}$$

$$= \frac{x^2 - 6x + 8}{4x^{\frac{1}{2}}}$$

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

Question 8 continued

$$\int_2^4 \frac{1}{4}x^{\frac{3}{2}} - \frac{3}{2}x^{\frac{1}{2}} + 2x^{-\frac{1}{2}} \quad dx$$

$$\left[\frac{1}{10}x^{\frac{5}{2}} - x^{\frac{3}{2}} + 4x^{\frac{1}{2}}\right]_2^4$$

$$\left(\frac{1}{10}(4)^{\frac{5}{2}} - 4^{\frac{3}{2}} + 4(4)^{\frac{1}{2}}\right) - \left(\frac{1}{10}(2)^{\frac{5}{2}} - (2)^{\frac{3}{2}} + 4(2)^{\frac{1}{2}}\right)$$

$$\frac{16}{5} - \left(\frac{1}{10}(\sqrt{2})^5 - (\sqrt{2})^3 + 4\sqrt{2}\right)$$

$$\frac{16}{5} - \left(\frac{1}{10} \cdot 4\sqrt{2} - 2\sqrt{2} + 4\sqrt{2}\right)$$

$$\underline{\underline{\frac{16}{5} - \frac{12}{5}\sqrt{2}}}$$

Question 8 continued

Question 8 continued

(Total for Question 8 is 6 marks)

9.

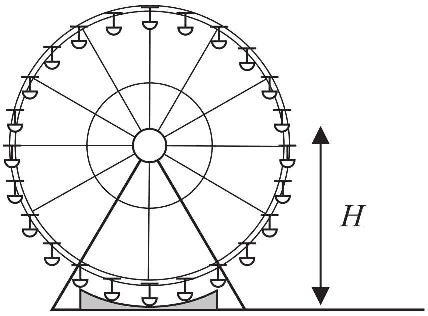


Figure 4

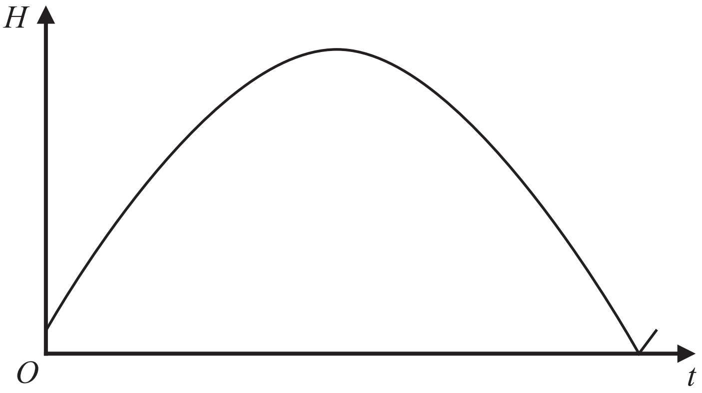


Figure 5

Figure 4 shows a sketch of a Ferris wheel.

The height above the ground, H m, of a passenger on the Ferris wheel, t seconds after the wheel starts turning, is modelled by the equation

$$H = |A\sin(bt + \alpha)°|$$

where A, b and α are constants.

Figure 5 shows a sketch of the graph of H against t, for one revolution of the wheel.

Given that

- the maximum height of the passenger above the ground is 50 m $A = 50$
- the passenger is 1 m above the ground when the wheel starts turning when $t = 0$ $H = 1$
- the wheel takes 720 seconds to complete one revolution $b = \frac{1}{4}$

180×4

(a) find a complete equation for the model, giving the exact value of A, the exact value of b and the value of α to 3 significant figures.

(4)

(b) Explain why an equation of the form

$$H = |A\sin(bt + \alpha)°| + d$$

where d is a positive constant, would be a more appropriate model.

(1)

a/ $H = \left|50 \sin\left(\frac{1}{4}t + \alpha\right)\right|$ when $t = 0$ $H = 1$

$1 = |50 \sin \alpha|$

$\pm\frac{1}{50} = \sin \alpha$

$\alpha = 1.15°$

$H = \left| 50 \sin\left(\frac{1}{4}t + 1.15\right) \right|$

b/ because the passengers should not touch the ground.

(Total for Question 9 is 5 marks)

10. The function f is defined by

$$f(x) = \frac{8x+5}{2x+3} \qquad x > -\frac{3}{2}$$

(a) Find $f^{-1}\left(\frac{3}{2}\right)$

(2)

(b) Show that

$$f(x) = A + \frac{B}{2x+3}$$

where *A* and *B* are constants to be found.

(2)

The function g is defined by

$$g(x) = 16 - x^2 \qquad 0 \leqslant x \leqslant 4$$

(c) State the range of g^{-1}

(1)

(d) Find the range of $f\,g^{-1}$

(3)

a/ $\frac{3}{2} = \frac{8x+5}{2x+3}$

$3(2x+3) = 2(8x+5)$

$6x + 9 = 16x + 10$

$-1 = 10x$

$x = -\frac{1}{10}$

$\therefore f^{-1}\left(\frac{3}{2}\right) = -\frac{1}{10}$

b/ $2x+3 \overline{)8x+5}$ quotient 4

$8x + 12$

-7

Question 10 continued

$4 - \frac{7}{2x+3}$

c/ $0 \leq g^{-1}(x) \leq 4$ (same as domain of $g(x)$)

d/ $f(0) = 4 - \frac{7}{3} = \frac{5}{3}$

$f(4) = 4 - \frac{7}{2(4)+3} = \frac{37}{11}$

$\frac{5}{3} \leq fg^{-1} \leq \frac{37}{11}$

Question 10 continued

Question 10 continued

(Total for Question 10 is 8 marks)

11. Prove, using algebra, that

$$n(n^2 + 5)$$

is even for all $n \in \mathbb{N}$.

(4)

if n is even : let $n = 2m$

$2m((2m)^2 + 5)$

$2m(4m^2+5)$

$8m^3 + 10m$

$2(4m^3+5m)$ $\therefore$ even

if n is odd: let $n = 2m+1$

$(2m+1)((2m+1)^2 + 5)$

$(2m+1)(4m^2 + 4m + 1 + 5)$

$(2m+1)(4m^2+4m+6)$

$2(2m+1)(2m^2+2m+3)$ $\therefore$ even

if n is even or odd $n(n^2+5)$ is even

Question 11 continued

(Total for Question 11 is 4 marks)

12. The function f is defined by

$$f(x) = \frac{e^{3x}}{4x^2 + k}$$

where k is a positive constant.

(a) Show that

$$f'(x) = (12x^2 - 8x + 3k)\,g(x)$$

where $g(x)$ is a function to be found.

(3)

Given that the curve with equation $y = f(x)$ has at least one stationary point,

(b) find the range of possible values of k.

(3)

a/ $u = e^{3x}$ $\quad$ $v = 4x^2 + k$

$\frac{du}{dx} = 3e^{3x}$ $\quad$ $\frac{dv}{dx} = 8x$

$$f'(x) = 3e^{3x}(4x^2 + k) + 8xe^{3x}$$

$$= 12x^2e^{3x} + 3ke^{3x} + 8xe^{3x}$$

$$= e^{3x}(12x^2 + 8x + 3k)$$

$a = 12 \quad b = 8 \quad c = 3k$

$$b^2 - 4ac \geqslant 0$$

$$(8)^2 - 4(12)(3k) \geqslant 0$$

$$64 - 144k \geqslant 0$$

$$64 \geqslant 144k$$

$$\frac{4}{9} \geqslant k$$

k is a positive constant $\therefore$ $\underline{\underline{0 < k \leqslant \frac{4}{9}}}$

Question 12 continued

(Total for Question 12 is 6 marks)

13. Relative to a fixed origin O

- the point A has position vector $4\mathbf{i} - 3\mathbf{j} + 5\mathbf{k}$
- the point B has position vector $4\mathbf{j} + 6\mathbf{k}$
- the point C has position vector $-16\mathbf{i} + p\mathbf{j} + 10\mathbf{k}$

where p is a constant.

Given that A, B and C lie on a straight line,

(a) find the value of p.

(3)

The line segment OB is extended to a point D so that $\overrightarrow{CD}$ is parallel to $\overrightarrow{OA}$

(b) Find $\left|\overrightarrow{OD}\right|$, writing your answer as a fully simplified surd.

(3)

a/ $\overrightarrow{AB} = \begin{pmatrix} 0 \\ 4 \\ 6 \end{pmatrix} - \begin{pmatrix} 4 \\ -3 \\ 5 \end{pmatrix} = \begin{pmatrix} -4 \\ 7 \\ 1 \end{pmatrix}$

$\overrightarrow{BC} = x\begin{pmatrix} -4 \\ 7 \\ 1 \end{pmatrix}$ (a multiple or $\overrightarrow{AB}$)

$$\begin{pmatrix} 0 \\ 4 \\ 6 \end{pmatrix} + x\begin{pmatrix} -4 \\ 7 \\ 1 \end{pmatrix} = \begin{pmatrix} -16 \\ p \\ 10 \end{pmatrix}$$

k// $6 + x = 10$

$\underline{\underline{x = 4}}$

j// $4 + 7(4) = p$

$\underline{\underline{p = 32}}$

b/ $\overrightarrow{OA} = \begin{pmatrix} 4 \\ -3 \\ 5 \end{pmatrix}$

$\overrightarrow{CD} = x\begin{pmatrix} 4 \\ -3 \\ 5 \end{pmatrix}$ a multiple of $\overrightarrow{OA}$

$\overrightarrow{OD} = y\begin{pmatrix} 0 \\ 4 \\ 6 \end{pmatrix}$ a multiple or $\overrightarrow{OB}$

Question 13 continued

$$\overrightarrow{OC} + \overrightarrow{CD} = \overrightarrow{OD}$$

$$\begin{pmatrix} -16 \\ 32 \\ 10 \end{pmatrix} + \begin{pmatrix} 4x \\ -3x \\ 5x \end{pmatrix} = \begin{pmatrix} 0 \\ 4y \\ 6y \end{pmatrix}$$

i// $-16 + 4x = 0$

$\underline{\underline{x = 4}}$

k// $10 + 5(4) = 6y$

$30 = 6y$

$\underline{\underline{y = 5}}$

$\therefore \overrightarrow{OD} = \begin{pmatrix} 0 \\ 20 \\ 30 \end{pmatrix}$

$|\overrightarrow{OD}| = \sqrt{20^2 + 30^2}$

$= 10\sqrt{13}$

Question 13 continued

Question 13 continued

(Total for Question 13 is 6 marks)

14. (a) Express $\dfrac{3}{(2x-1)(x+1)}$ in partial fractions.

(3)

When chemical *A* and chemical *B* are mixed, oxygen is produced.

A scientist mixed these two chemicals and measured the total volume of oxygen produced over a period of time.

The total volume of oxygen produced, $V\,\text{m}^3$, t hours after the chemicals were mixed, is modelled by the differential equation

$$\frac{\mathrm{d}V}{\mathrm{d}t} = \frac{3V}{(2t-1)(t+1)} \qquad V \geqslant 0 \qquad t \geqslant k$$

where k is a constant.

Given that exactly 2 hours after the chemicals were mixed, a total volume of $3\,\text{m}^3$ of oxygen had been produced,

(b) solve the differential equation to show that

$$V = \frac{3(2t-1)}{(t+1)}$$

(5)

The scientist noticed that

- there was a **time delay** between the chemicals being mixed and oxygen being produced
- there was a **limit** to the total volume of oxygen produced

Deduce from the model

(c) (i) the **time delay** giving your answer in minutes,

(ii) the **limit** giving your answer in m^3

(2)

a/ $\dfrac{3}{(2x-1)(x+1)} = \dfrac{A}{2x-1} + \dfrac{B}{x+1}$

$3 = A(x+1) + B(2x-1)$

Let $x = -1$

$3 = -3B$

$\underline{\underline{B = -1}}$

Let $x = 1/2$ $\quad 3 = \frac{3}{2}A$

$\underline{\underline{A = 2}}$

$$\frac{2}{2x-1} - \frac{1}{x+1}$$

b/ $\int \frac{1}{v}\,dv = \int \frac{3}{(2t-1)(t+1)}\,dt$ when $t=2$ $v=3$

$$\int \frac{1}{v}\,dv = \int \frac{2}{2t-1} - \frac{1}{t+1}\,dt$$

$$\ln v = \ln(2t-1) - \ln(t+1) + c$$

$$\ln 3 = \ln 3 - \ln 3 + c$$

$$c = \ln 3$$

$$\ln v = \ln(2t-1) - \ln(t+1) + \ln 3$$

$$\ln v = \ln \frac{3(2t-1)}{t+1}$$

$$\underline{\underline{v = \frac{3(2t-1)}{t+1}}}$$

ci/ $0 = \frac{3(2t-1)}{t+1}$

$0 = 3(2t-1)$

$0 = 2t-1$

$1 = 2t$

$t = 1/2$ = 30 minutes

ii/ $v = \frac{6t-3}{t+1}$

as t icreases v approaches 6 $\therefore$ $\underline{\underline{6\,m^3}}$

Question 14 continued

Question 14 continued

(Total for Question 14 is 10 marks)

15. **In this question you must show all stages of your working.**

Solutions relying on calculator technology are not acceptable.

Given that the first three terms of a geometric series are

$$12\cos\theta \qquad 5 + 2\sin\theta \qquad \text{and} \qquad 6\tan\theta$$

(a) show that

$$4\sin^2\theta - 52\sin\theta + 25 = 0$$

(3)

Given that θ is an obtuse angle measured in radians,

(b) solve the equation in part (a) to find the exact value of θ

(2)

(c) show that the sum to infinity of the series can be expressed in the form

$$k(1 - \sqrt{3})$$

where k is a constant to be found.

(5)

a/ $\dfrac{5+2\sin\theta}{12\cos\theta} = \dfrac{6\tan\theta}{5+2\sin\theta}$

$(5+2\sin\theta)(5+2\sin\theta) = 72\tan\theta\cos\theta$

$25 + 20\sin\theta + 4\sin^2\theta = 72\left(\dfrac{\sin\theta}{\cos\theta}\right)\cos\theta$

$25 + 20\sin\theta + 4\sin^2\theta = 72\sin\theta$

$4\sin^2\theta - 52\sin\theta + 25 = 0$

b/ $\sin\theta = \dfrac{25}{2}$ ✗ $\qquad \underline{\underline{\sin\theta = \dfrac{1}{2}}}$

$\theta = \dfrac{1}{6}\pi, \dfrac{5}{6}\pi$

θ is obtuse $\therefore \underline{\underline{\dfrac{5}{6}\pi}}$

Question 15 continued

c/ $S_\infty = \frac{a}{1-r}$

$a = 12 \cos\left(\frac{5}{6}\pi\right)$

$= -6\sqrt{3}$

$r = \frac{5+2\sin\left(\frac{5}{6}\pi\right)}{-6\sqrt{3}}$

$= -\frac{\sqrt{3}}{3}$

$S_\infty = \frac{-6\sqrt{3}}{1-\left(-\frac{\sqrt{3}}{3}\right)}$

$= \frac{-6\sqrt{3}}{1+\frac{\sqrt{3}}{3}}$

$= \frac{(-18\sqrt{3})(3-\sqrt{3})}{(3+\sqrt{3})(3-\sqrt{3})}$

$= \frac{-54\sqrt{3}+54}{6}$

$= -9\sqrt{3}+9$

$= \underline{\underline{9(1-\sqrt{3})}}$

Question 15 continued

Question 15 continued

(Total for Question 15 is 10 marks)

16.

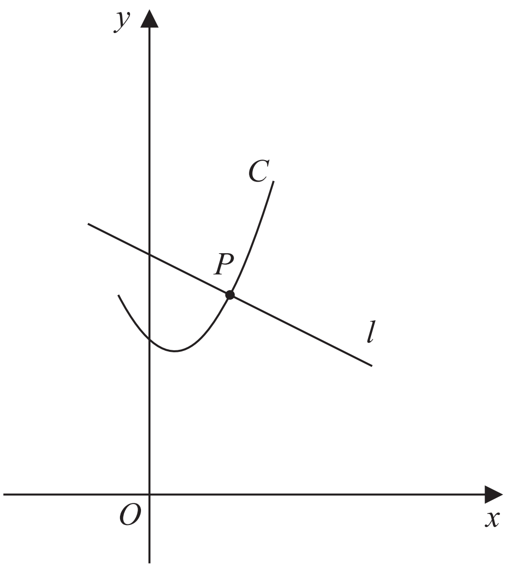


Figure 6

Figure 6 shows a sketch of the curve C with parametric equations

$$x = 2\tan t + 1 \qquad y = 2\sec^2 t + 3 \qquad -\frac{\pi}{4} \leqslant t \leqslant \frac{\pi}{3}$$

The line l is the normal to C at the point P where $t = \frac{\pi}{4}$

(a) Using parametric differentiation, show that an equation for l is

$$y = -\frac{1}{2}x + \frac{17}{2}$$

(5)

(b) Show that all points on C satisfy the equation

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

(2)

The straight line with equation

$$y = -\frac{1}{2}x + k \qquad \text{where } k \text{ is a constant}$$

intersects C at two distinct points.

(c) Find the range of possible values for k.

(5)

a/ $\frac{dx}{dt} = 2\sec^2 t$ $\quad 1 + \tan^2 x = \sec^2 x$

$y = 2(1+\tan^2 t) + 3$

$= 2 + 2\tan^2 t + 3$

Question 16 continued

$$y = 5 + 2(\tan t)^2$$

$$\frac{dy}{dt} = 4 \tan t \sec^2 t$$

$$\frac{dy}{dx} = \frac{4 \tan t \sec^2 t}{2 \sec^2 t}$$

$$= \underline{\underline{2 \tan t}}$$

when $t = \frac{\pi}{4}$ $\frac{dy}{dx} = 2$

$\therefore$ m of normal $= -\frac{1}{2}$

when $t = \frac{\pi}{4}$ $x = 2 \tan\left(\frac{\pi}{4}\right) + 1$ $y = 2 \frac{1}{(\cos \frac{\pi}{4})^2} + 3$

$= 3$ $= 7$

$$y - y_1 = m(x - x_1)$$

$$y - 7 = \frac{-1}{2}(x - 3)$$

$$2y - 14 = -x + 3$$

$$2y = -x + 17$$

$$y = -\frac{1}{2}x + \frac{17}{2}$$

b/ $x - 1 = 2 \tan t$

$$(x-1)^2 = 4 \tan^2 t$$

$$(x-1)^2 = 4(\sec^2 t - 1)$$

$$(x-1)^2 = 4 \sec^2 t - 4$$

$$y = 2\sec^2 t + 3$$

$$y - 3 = 2 \sec^2 t$$

$$2y - 6 = 4 \sec^2 t$$

Question 16 continued

$$(x-1)^2 = 2y - 6 - 4$$

$$(x-1)^2 = 2y - 10$$

$$(x-1)^2 + 10 = 2y$$

$$\underline{\underline{\frac{1}{2}(x-1)^2 + 5 = y}}$$

c/ $y = \frac{1}{2}(x-1)^2 + 5$ $\qquad$ $y = -\frac{1}{2}x + k$

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

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

$$x^2 - 2x + 1 + 10 = -x + 2k$$

$$x^2 - x + 11 - 2k = 0$$

$a = 1 \quad b = -1 \quad c = 11 - 2k$

$$b^2 - 4ac > 0$$

$$(-1)^2 - 4(1)(11 - 2k) > 0$$

$$1 - 44 + 8k > 0$$

$$8k > 43$$

$$\underline{\underline{k > \frac{43}{8}}}$$

Max limit is when $t = -\frac{\pi}{4}$ (see graph)

$x = 2\tan\left(-\frac{\pi}{4}\right) + 1$ $\qquad$ $y = 2\frac{1}{\left(\cos -\frac{\pi}{4}\right)^2} + 3 = 7$

$= -1$

Question 16 continued

$y = -\frac{1}{2}x + k$

$7 = -\frac{1}{2}(-1) + k$

$\frac{13}{2} = k$

$\frac{43}{8} < k \leq \frac{13}{2}$

Question 16 continued

(Total for Question 16 is 12 marks)

TOTAL FOR PAPER IS 100 MARKS