

1. The first three terms in ascending powers of  $x$  in the binomial expansion of  $(1 + px)^8$  are given by

$$1 + 12x + qx^2$$

where  $p$  and  $q$  are constants.

Find the value of  $p$  and the value of  $q$ .

(5)

$$(1 + px)^8 = 1 + 12x + qx^2 + \dots$$

$$\text{LHS} = 1^8 + 8(1)^7(px) + 28(1)^6p^2x^2 + \dots$$

$$\therefore 8p = 12 \Rightarrow p = \frac{3}{2}$$

$$28p^2 = q \Rightarrow q = 63$$

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2. Find the range of values of  $x$  for which

(a)  $4(x-2) \leq 2x+1$  (2)

(b)  $(2x-3)(x+5) > 0$  (3)

(c) both  $4(x-2) \leq 2x+1$  and  $(2x-3)(x+5) > 0$  (1)

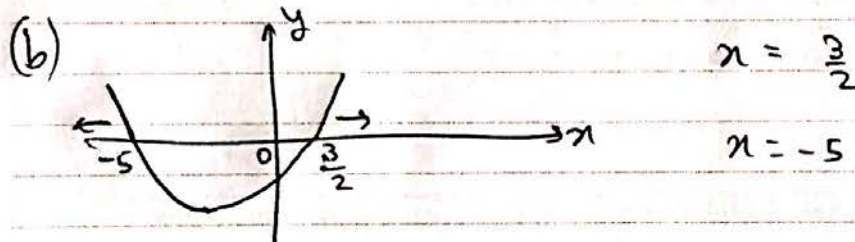
(a),  $4x-8 \leq 2x+1$

$$\therefore 2x \leq 9$$

$$\therefore x \leq \frac{9}{2}$$

~~(b)  $(2x-3)(x+5) = 2x^2 + 7x - 15$~~

~~$$\therefore 2x^2 + 7x - 15$$~~



$$\therefore x > \frac{3}{2} \quad x < -5$$

(c)  $\left\{ \frac{3}{2} < x \leq \frac{9}{2} \right\} \cup \{ x < -5 \}$



3. Answer this question without a calculator, showing all your working and giving your answers in their simplest form.

(i) Solve the equation

$$4^{2x+1} = 8^{4x} \quad (3)$$

(ii) (a) Express

$$3\sqrt{18} - \sqrt{32}$$

in the form  $k\sqrt{2}$ , where  $k$  is an integer. (2)

(b) Hence, or otherwise, solve

$$3\sqrt{18} - \sqrt{32} = \sqrt{n} \quad (2)$$

$$(i) \quad 4^{2x+1} = 8^{4x}$$

$$\therefore (2^2)^{2x+1} = (2^3)^{4x}$$

$$\therefore 2^{4x+2} = 2^{12x}$$

$$\Rightarrow 4x+2 = 12x \Rightarrow 8x = 2 \therefore x = \frac{1}{4}$$

$$(ii) (a). \quad 3\sqrt{18} - \sqrt{32} = 3\sqrt{9 \cdot 2} - \sqrt{16 \cdot 2}$$

$$= 9\sqrt{2} - 4\sqrt{2}$$

$$\therefore 3\sqrt{18} - \sqrt{32} = 5\sqrt{2} \quad k = 5$$

$$(c) \quad 5\sqrt{2} = \sqrt{n}$$

$$(5\sqrt{2})^2 = (\sqrt{n})^2 \Rightarrow n = 50$$

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4.

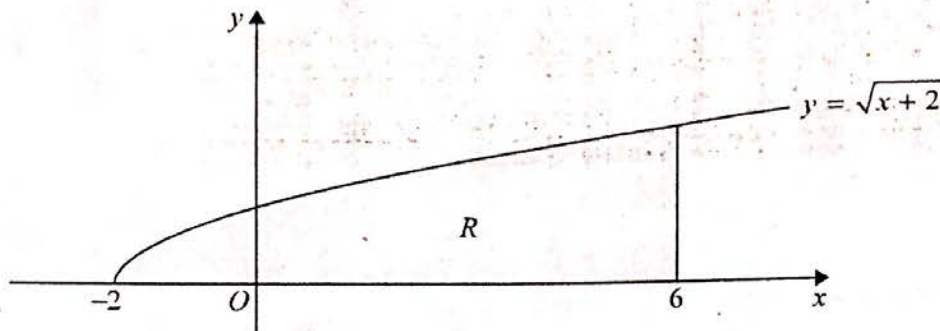


Figure 1

Figure 1 shows a sketch of part of the curve with equation  $y = \sqrt{x+2}$ ,  $x \geq -2$

The finite region  $R$ , shown shaded in Figure 1, is bounded by the curve, the  $x$ -axis and the line  $x = 6$

The table below shows corresponding values of  $x$  and  $y$  for  $y = \sqrt{x+2}$

$x$	-2	0	2	4	6
$y$	0	1.4142	2	2.4495	2.8284

(a) Complete the table above, giving the missing value of  $y$  to 4 decimal places. (1)

(b) Use the trapezium rule, with all of the values of  $y$  in the completed table, to find an approximate value for the area of  $R$ , giving your answer to 3 decimal places. (3)

Use your answer to part (b) to find approximate values of

(c) (i)  $\int_{-2}^6 \frac{\sqrt{x+2}}{2} dx$

(ii)  $\int_{-2}^6 (2 + \sqrt{x+2}) dx$  (4)

(b) Area  $R \approx \left(\frac{1}{2}\right)\left(\frac{8}{4}\right) [0 + 2(1.4142 + 2 + 2.4495) + 2.8284]$   
 $= 14.556$  (3dp)

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Question 4 continued

$$(c)(i) \int_{-2}^6 \frac{\sqrt{x+2}}{2} dx = \frac{1}{2} \int_{-2}^6 \sqrt{x+2} dx \approx \frac{1}{2} \times 14.556 \\ = \underline{\underline{7.278}}$$

$$(ii) \int_{-2}^6 2 + \sqrt{x+2} dx = \int_{-2}^6 2 dx + \int_{-2}^6 \sqrt{x+2} dx$$

$$\approx [2x]_{-2}^6 + 14.556$$

$$= 16 + 14.556 = \underline{\underline{30.556}}$$

5. (i)

$$U_{n+1} = \frac{U_n}{U_n - 3}, \quad n \geq 1$$

Given  $U_1 = 4$ , find

(a)  $U_2$

(1)

(b)  $\sum_{n=1}^{100} U_n$

(2)

(ii) Given

$$\sum_{r=1}^n (100 - 3r) < 0$$

find the least value of the positive integer  $n$ .

(3)

$$5(i)(a) \quad U_2 = \frac{4}{4-3} = 4$$

$$(b) \quad U_1 = U_2 = U_3 = U_4 = U_5 = \dots = U_n = 4$$

$$\sum_{n=1}^{100} U_n = \sum_{n=1}^{100} 4 = 4 \times 100 = 400$$

$$(ii) \quad \sum_{r=1}^n (100 - 3r) = \sum_{r=1}^n 100 - 3 \sum_{r=1}^n r$$

$$= 100n - \frac{3n}{2}(n+1)$$

$$\therefore 100n - \frac{3n}{2}(n+1) < 0$$

$$\therefore 100n - \frac{3}{2}n^2 - \frac{3n}{2} < 0$$

$$200n - 3n^2 - 3n < 0$$

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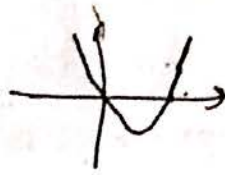
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$$\therefore 3n^2 - 197n > 0$$

$$n(3n - 197) > 0$$



$$\text{C.V. } n = \frac{197}{3} = 65.66\dots$$

$$\Rightarrow n = \underline{\underline{66}}$$

6. (a) Show that  $\frac{x^2 - 4}{2\sqrt{x}}$  can be written in the form  $Ax^p + Bx^q$ , where  $A$ ,  $B$ ,  $p$  and  $q$  are constants to be determined. (3)

(b) Hence find

$$\int \frac{x^2 - 4}{2\sqrt{x}} dx, \quad x > 0$$

giving your answer in its simplest form. (4)

~~$$\frac{x^2 - 4}{2\sqrt{x}} = \frac{x^2}{2\sqrt{x}} - \frac{4}{2\sqrt{x}} = \frac{x^{5/2}}{2} - 2x^{1/2}$$~~

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

~~$$= \frac{1}{2} x^{3/2} - \frac{2x\sqrt{x}}{\sqrt{x} \times \sqrt{x}}$$~~

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

$$A = \frac{1}{2}$$

$$B = -2$$

$$p = 3/2$$

$$q = -1/2$$

$$(b) \int \frac{1}{2} x^{3/2} - 2x^{-1/2} dx$$

$$= \frac{1}{5} x^{5/2} - 4x^{1/2} + C$$

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7.

$$f(x) = 3x^3 + ax^2 + bx - 10, \text{ where } a \text{ and } b \text{ are constants.}$$

Given that  $(x - 2)$  is a factor of  $f(x)$ ,

(a) use the factor theorem to show that  $2a + b = -7$  (2)

Given also that when  $f(x)$  is divided by  $(x + 1)$  the remainder is  $-36$

(b) find the value of  $a$  and the value of  $b$ . (4)

$f(x)$  can be written in the form

$$f(x) = (x - 2)Q(x), \text{ where } Q(x) \text{ is a quadratic function.}$$

(c) (i) Find  $Q(x)$ .

(ii) Prove that the equation  $f(x) = 0$  has only one real root.

You must justify your answer and show all your working.

(4)

7

(a)  $(x-2)$  as a factor implies  $x=2$  is a root of  $f(x)=0$

$$\therefore f(2) = 3(2)^3 + a(2)^2 + 2b - 10 = 0$$

$$f(2) = 24 + 4a + 2b - 10$$

$$= 4a + 2b + 14 = 0$$

$$\therefore 4a + 2b = -14$$

$$\downarrow \div 2 \Rightarrow 2a + b = -7 \quad \#$$

(b)  $f(-1) = -36$

$$f(-1) =$$

$$\Rightarrow -3 + a - b - 10 = -36$$

$$\therefore a - b = -23$$



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$$2a + b + a - b = 3a = -7 - 23 = -30$$

$$\therefore a = -10$$

$$\Rightarrow b = a + 23 = -10 + 23 = 13$$

$$a = -10$$

$$b = 13$$

(c) (i)

$$3x^3 - 10x^2 + 13x - 10 = (x-2)[3x^2 + kx + 5]$$

$$\begin{aligned} \therefore 3x^3 - 10x^2 + 13x - 10 &= 3x^3 + kx^2 + 5x - 6x^2 - 2kx - 10 \\ &= 3x^3 + (k-6)x^2 + (5-2k)x - 10 \end{aligned}$$

$$\Rightarrow k - 6 = -10$$

$$\Rightarrow k = -4$$

$$\therefore Q(x) = 3x^2 - 4x + 5$$

$$(ii) f(x) = 0 \Rightarrow (x-2)(3x^2 - 4x + 5) = 0$$

$$\Rightarrow x - 2 = 0 \quad \therefore x = \underline{2}$$

$$Q(x) = 0 \quad \text{Discriminant of } Q(x) = b^2 - 4ac = (-4)^2 - 4(3)(5) = -44 < 0$$

$$\therefore b^2 - 4ac < 0 \quad \Rightarrow Q(x) \text{ has no real roots.}$$

$\therefore x = 2$  is  
the only root

8. In this question the angle  $\theta$  is measured in degrees throughout.

(a) Show that the equation

$$\frac{5 + \sin \theta}{3 \cos \theta} = 2 \cos \theta, \quad \theta \neq (2n+1)90^\circ, \quad n \in \mathbb{Z}$$

may be rewritten as

$$6 \sin^2 \theta + \sin \theta - 1 = 0 \quad (3)$$

(b) Hence solve, for  $-90^\circ < \theta < 90^\circ$ , the equation

$$\frac{5 + \sin \theta}{3 \cos \theta} = 2 \cos \theta$$

Give your answers to one decimal place, where appropriate.

8(a).  $\frac{5 + \sin \theta}{3 \cos \theta} = 2 \cos \theta$  (4)

$\times 3 \cos \theta \Rightarrow 5 + \sin \theta = 6 \cos^2 \theta$

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

$\therefore 5 + \sin \theta = 6 - 6 \sin^2 \theta$

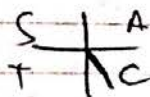
$\therefore 6 \sin^2 \theta + \sin \theta - 1 = 0$  II

(b)  $(3 \sin \theta - 1)(2 \sin \theta + 1) = 0$

$\sin \theta = \frac{1}{3} \Rightarrow \theta = 19.5^\circ$  (1dp)



$\sin \theta = -\frac{1}{2} \Rightarrow \theta = -30^\circ$



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9. The first term of a geometric series is 6 and the common ratio is 0.92

For this series, find

- (a) (i) the 25<sup>th</sup> term, giving your answer to 2 significant figures,
- (ii) the sum to infinity. (4)

The sum to  $n$  terms of this series is greater than 72

- (b) Calculate the smallest possible value of  $n$ . (4)

9(a) ~~(i)~~  $a = 6$        $r = 0.92$

(i)  $u_{25} = 6 \times 0.92^{24}$   
 $= \underline{\underline{0.81}}$  (2sf)

(ii)  $S_{\infty} = \frac{6}{1-0.92} = \underline{\underline{75}}$

(b)  $S_n > 72$

$\therefore \frac{6(1-0.92^n)}{1-0.92} > 72$

~~1~~  $6(1-0.92^n) > 5.76$

$1-0.92^n > 0.96$

$0.92^n < 0.04$

$n \log 0.92 < \log 0.04 \Rightarrow n > 38.6 \dots \Rightarrow \underline{\underline{n = 39}}$

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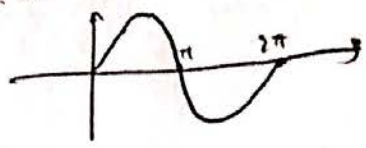
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10. The curve  $C$  has equation  $y = \sin\left(x + \frac{\pi}{4}\right)$ ,  $0 \leq x \leq 2\pi$

(a) On the axes below, sketch the curve  $C$ .



(2)

(b) Write down the exact coordinates of all the points at which the curve  $C$  meets or intersects the  $x$ -axis and the  $y$ -axis.

(3)

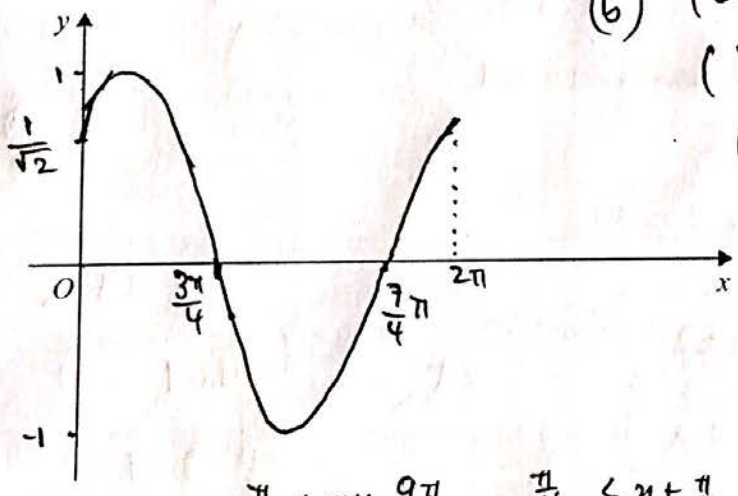
(c) Solve, for  $0 \leq x \leq 2\pi$ , the equation

$$\sin\left(x + \frac{\pi}{4}\right) = \frac{\sqrt{3}}{2}$$

giving your answers in the form  $k\pi$ , where  $k$  is a rational number.

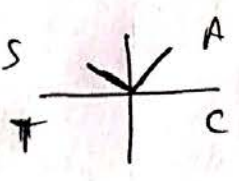
(4)

(a)



- (b)  $(0, \frac{1}{2})$   
 $(\frac{3\pi}{4}, 0)$   
 $(\frac{7\pi}{4}, 0)$

(c)



$$\frac{\pi}{4} \leq x + \frac{\pi}{4} \leq \frac{9\pi}{4}$$

$$\left(x + \frac{\pi}{4}\right) = \arcsin \frac{\sqrt{3}}{2} = \frac{\pi}{3} \quad x = \frac{1}{12} \pi$$

$$\left(x + \frac{\pi}{4}\right) = \frac{2\pi}{3} \quad x = \frac{5}{12} \pi$$

$$\left(x + \frac{\pi}{4}\right) = \frac{7\pi}{3} \quad x = \frac{25}{12} \pi$$

X reject (outside range)

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11.

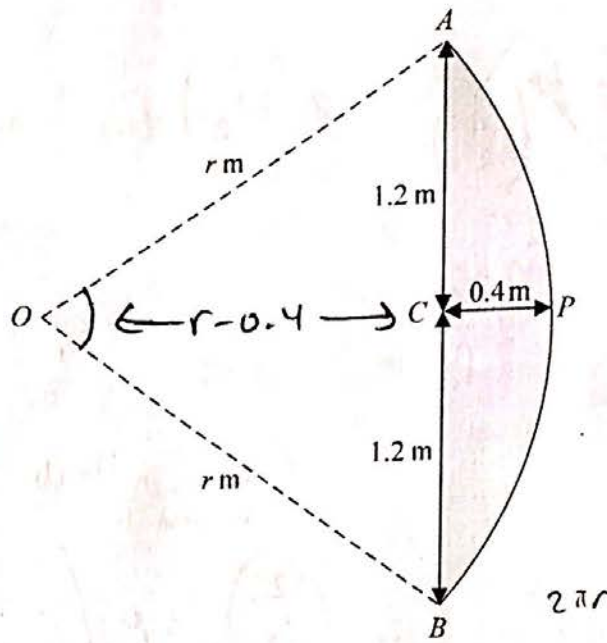


Diagram not drawn to scale

Figure 2

Figure 2 shows the design for a sail  $APBCA$ .

The curved edge  $APB$  of the sail is an arc of a circle centre  $O$  and radius  $r$  m.

The straight edge  $ACB$  is a chord of the circle.

The height  $AB$  of the sail is 2.4 m.

The maximum width  $CP$  of the sail is 0.4 m.

- (a) Show that  $r = 2$  (2)
- (b) Show, to 4 decimal places, that angle  $AOB = 1.2870$  radians. (2)
- (c) Hence calculate the area of the sail, giving your answer, in  $m^2$ , to 3 decimal places. (4)

(a)

$$(r-0.4)^2 + 1.2^2 = r^2$$

$$\therefore r^2 - 0.8r + 1.6 = r^2$$

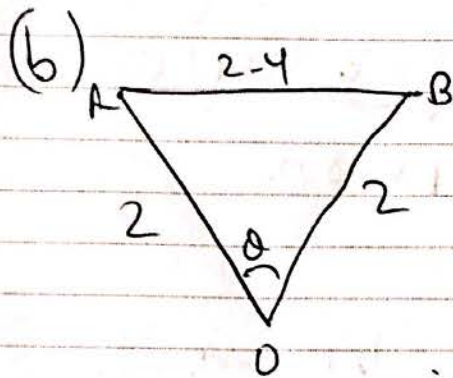
$$\therefore 0.8r = 1.6$$

$$\Rightarrow r = 2 \text{ as required.}$$


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## Question 1 continued

(b) ~~Arc length AB =  $\angle AOB \times r^2$~~



$$\cos \theta = \frac{2^2 + 2^2 - 2.4^2}{2 \times 2 \times 2}$$

$$\therefore \cos \theta = \frac{7}{25}$$

$$\therefore \theta = \arccos\left(\frac{7}{25}\right) = 1.2870022 \dots$$

$$\therefore \angle AOB = 1.2870 \text{ (4dp)}$$

(c) Area of sail = Area of sector OAB - Area  $\Delta$  OAB

$$= \frac{1}{2} \arccos\left(\frac{7}{25}\right) \times 2^2 = \frac{1}{2} \times 2.4 \times 1.6$$

$$= 0.654 \text{ (3dp)}$$

12.

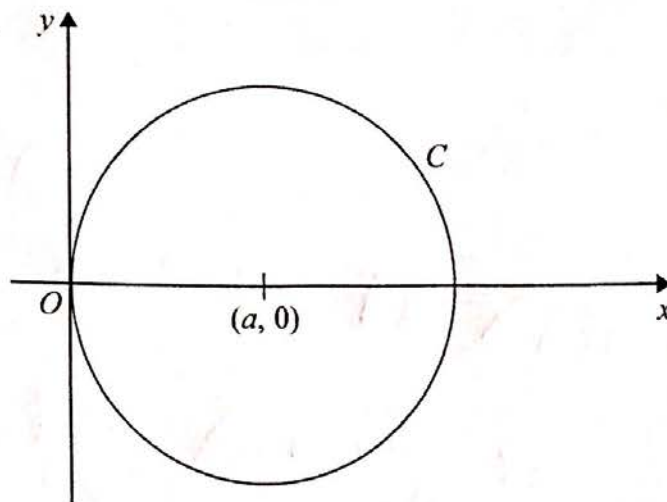


Figure 3

Figure 3 shows a circle  $C$

$C$  touches the  $y$ -axis and has centre at the point  $(a, 0)$  where  $a$  is a positive constant.

(a) Write down an equation for  $C$  in terms of  $a$

(2)

Given that the point  $P(4, -3)$  lies on  $C$ ,

(b) find the value of  $a$

(3)

$$(a) \quad (x-a)^2 + y^2 = a^2$$

$$(b) \quad (4-a)^2 + 9 = a^2$$

$$\therefore \cancel{25} + 25 - 8a + a^2 = a^2$$

$$\therefore a = \frac{25}{8}$$





13. (a) Show that the equation

$$2 \log_2 y = 5 - \log_2 x \quad x > 0, y > 0$$

may be written in the form  $y^2 = \frac{k}{x}$  where  $k$  is a constant to be found. (3)

(b) Hence, or otherwise, solve the simultaneous equations

$$2 \log_2 y = 5 - \log_2 x$$

$$\log_x y = -3$$

for  $x > 0, y > 0$

(5)

$$13(a). \quad 2 \log_2 y = 5 - \log_2 x$$

$$\therefore 2 \log_2 y + \log_2 x = 5$$

$$\therefore \log_2 y^2 + \log_2 x = 5$$

$$\therefore \log_2 (y^2 x) = 5$$

$$\therefore \log_2 (y^2 x) = 5 \log_2 2 = \log_2 2^5$$

$$= \log_2 32$$

$$\Rightarrow y^2 x = 32$$

$$\therefore y^2 = \frac{32}{x} \quad k = 32$$

$$(b) \log_x y = -3 \log_x x = \log_x x^{-3} \Rightarrow y = \frac{1}{x^3}$$

$$\therefore \left(\frac{1}{x^3}\right)^2 = \frac{32}{x}$$



$$y = \frac{1}{x^2} \quad \& \quad y^2 = \frac{32}{x}$$

$$\therefore \left( \frac{1}{x^2} \right)^2 = \frac{32}{x} \Rightarrow \frac{1}{x^4} = \frac{32}{x}$$

$$\therefore \frac{1 = 32}{x}$$

$$1 = 32x^5 \Rightarrow x^5 = \frac{1}{32}$$

$$\therefore x = \frac{1}{2} \Rightarrow y = \frac{1}{\left(\frac{1}{2}\right)^2}$$

$$y = 4$$

14.

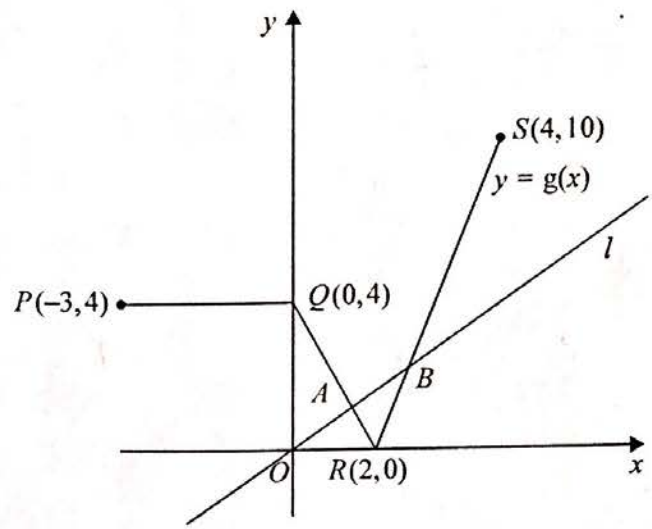


Figure 4

Figure 4 shows a sketch of the graph of  $y = g(x)$ ,  $-3 \leq x \leq 4$  and part of the line  $l$  with equation  $y = \frac{1}{2}x$

The graph of  $y = g(x)$  consists of three line segments, from  $P(-3, 4)$  to  $Q(0, 4)$ , from  $Q(0, 4)$  to  $R(2, 0)$  and from  $R(2, 0)$  to  $S(4, 10)$ .

The line  $l$  intersects  $y = g(x)$  at the points  $A$  and  $B$  as shown in Figure 4.

- (a) Use algebra to find the  $x$  coordinate of the point  $A$  and the  $x$  coordinate of the point  $B$ .

Show each step of your working and give your answers as exact fractions.

(6)

- (b) Sketch the graph with equation

$$y = \frac{3}{2}g(x), \quad -3 \leq x \leq 4$$

On your sketch show the coordinates of the points to which  $P, Q, R$  and  $S$  are transformed.

(2)

(a) Consider Qf: gradient = -2    c = 4

$$\Rightarrow y = -2x + 4$$

$$y = \frac{1}{2}x \Rightarrow \frac{1}{2}x = -2x + 4 \Rightarrow x_A = \frac{8}{5}$$

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Question 4 continued

Consider SR: gradient = 5

$$\therefore y = 5x + k$$

$$(2, 0) \Rightarrow 0 = 10 + k \Rightarrow k = -10$$

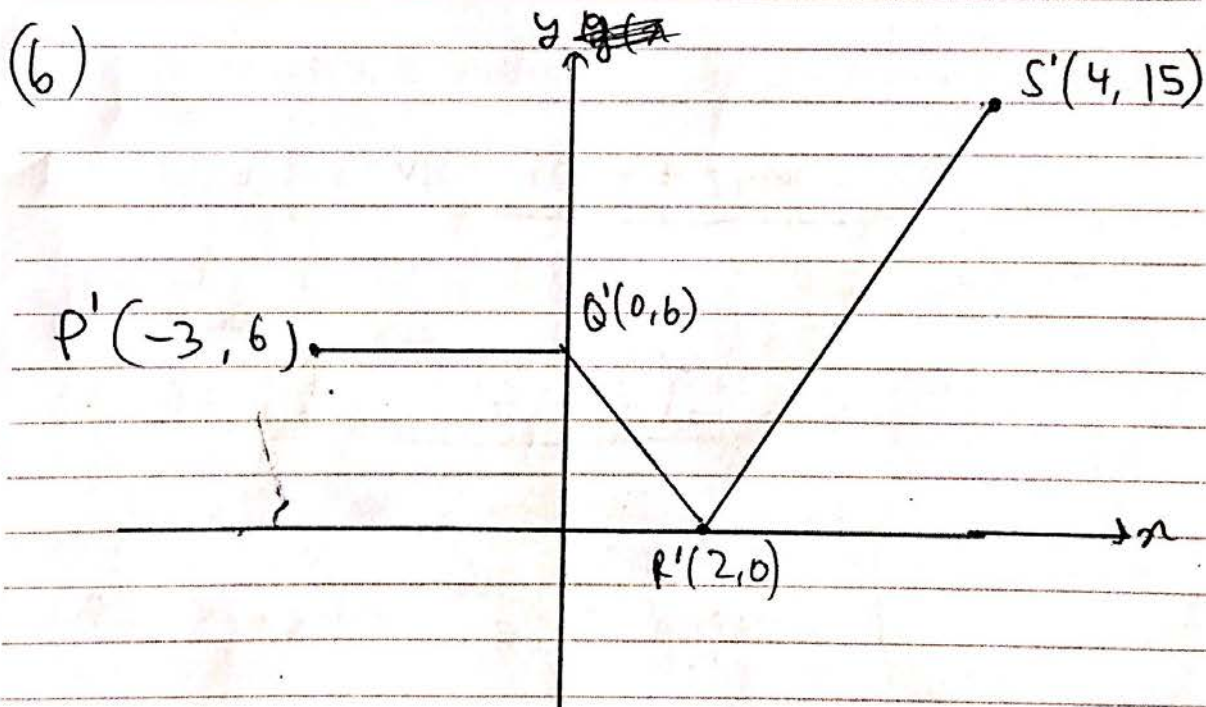
$$y = 5x - 10$$

$$y = \frac{1}{2}x \Rightarrow \frac{1}{2}x = 5x - 10$$

$$\frac{9}{2}x = 10$$

$$\therefore x_B = \frac{20}{9}$$

$$\therefore x_A = \frac{8}{5} \quad x_B = \frac{20}{9}$$



15.

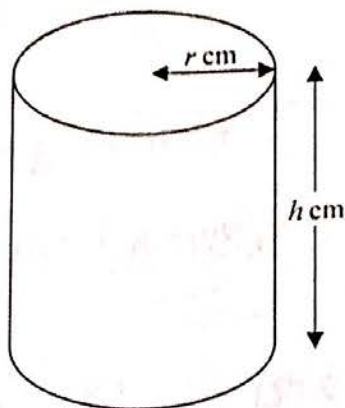


Figure 5

Figure 5 shows a design for a water barrel.

It is in the shape of a right circular cylinder with height  $h$  cm and radius  $r$  cm.

The barrel has a base but has no lid, is open at the top and is made of material of negligible thickness.

The barrel is designed to hold  $60\,000$  cm<sup>3</sup> of water when full.

- (a) Show that the total external surface area,  $S$  cm<sup>2</sup>, of the barrel is given by the formula

$$S = \pi r^2 + \frac{120\,000}{r} \quad (3)$$

- (b) Use calculus to find the minimum value of  $S$ , giving your answer to 3 significant figures. (6)

- (c) Justify that the value of  $S$  you found in part (b) is a minimum. (2)

$$(a) \quad V = \pi r^2 h = 60\,000 \Rightarrow h = \frac{60\,000}{\pi r^2} \quad (2)$$

$$\begin{aligned}
 S &= \text{[diagram of cylinder with lid]} + \text{[diagram of cylinder without lid]} = \cancel{\pi r^2} + 2\pi r h \\
 &= \pi r^2 + 2\pi r \left( \frac{60\,000}{\pi r^2} \right) \\
 &= \pi r^2 + \frac{120\,000}{r} \quad \text{as required.}
 \end{aligned}$$



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Question 5 continued

$$(b) \frac{\partial S}{\partial r} = 2\pi r - 120000r^{-2}$$

$$\frac{\partial S}{\partial r} = 0 \Rightarrow 2\pi r (-1)$$

$$\frac{2\pi r - 120000}{r^2} = 0$$

$$\therefore 2\pi r^3 - 120000 = 0$$

$$\therefore r^3 = \frac{60000}{\pi}$$

$$\Rightarrow r = 26.73 \dots$$

$$\therefore S = \pi (26.73 \dots)^2 + \frac{120000}{26.73 \dots}$$

$$S = 6730 \text{ (3sf)}$$

$$(c) \frac{\partial^2 S}{\partial r^2} = 2\pi + 240000r^{-3}$$

$$\left( \frac{\partial^2 S}{\partial r^2} \right)_{r=26.73 \dots} = 2\pi + 240000 (26.73 \dots)^{-3}$$

$$= 6\pi > 0$$

$$\therefore \left( \frac{\partial^2 S}{\partial r^2} \right)_{26.73 \dots} > 0 \Rightarrow S \text{ is a minimum}$$

6730

(Total 5 marks)

Q5

16.

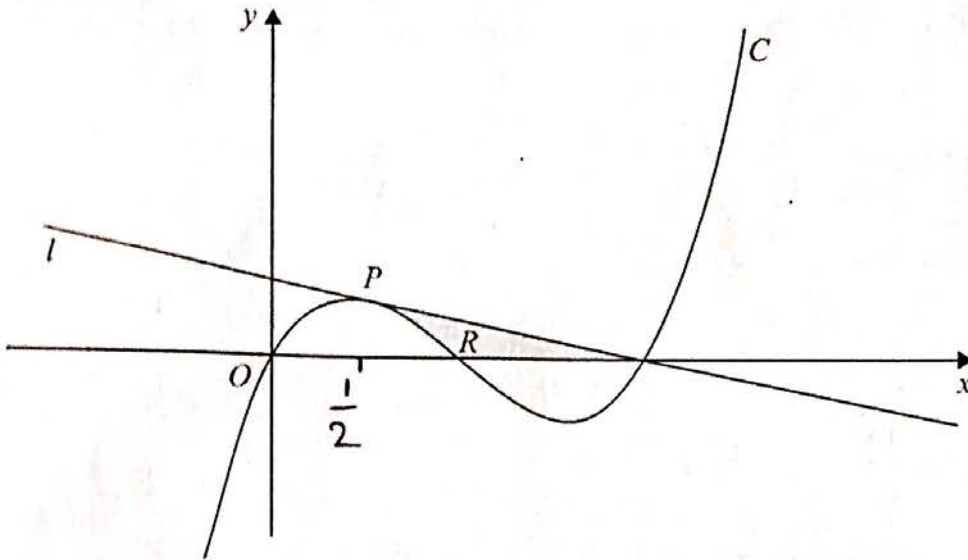


Figure 6

Figure 6 shows a sketch of part of the curve  $C$  with equation

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

The point  $P$  lies on  $C$  and has  $x$  coordinate  $\frac{1}{2}$

The line  $l$ , as shown on Figure 6, is the tangent to  $C$  at  $P$ .

(a) Find  $\frac{dy}{dx}$  (2)

(b) Use part (a) to find an equation for  $l$  in the form  $ax + by = c$ , where  $a$ ,  $b$  and  $c$  are integers. (4)

The finite region  $R$ , shown shaded in Figure 6, is bounded by the line  $l$ , the curve  $C$  and the  $x$ -axis.

The line  $l$  meets the curve again at the point  $(2, 0)$

(c) Use integration to find the exact area of the shaded region  $R$ . (6)

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

$\frac{dy}{dx} = 3x^2 - 6x + 2$

(b) Gradient @  $P = \left(\frac{dy}{dx}\right)_{x=0.5} = -\frac{1}{4}$



Question 8 continued

$$y_p = \frac{1}{2} \left( \frac{1}{2} - 1 \right) \left( \frac{1}{2} - 2 \right)$$

$$= \frac{3}{8} \quad \therefore p \left( \frac{1}{2}, \frac{3}{8} \right)$$

$$\therefore y - y_p = -\frac{1}{4} (x - x_p)$$

$$\therefore y - \frac{3}{8} = -\frac{1}{4} \left( x - \frac{1}{2} \right)$$

$$\therefore 8y - 3 = -2x + 1$$


$$\therefore 2x + 8y - 4 = 0$$

$$\therefore x + 4y = 2$$

$$a = 1$$

$$b = 4$$

$$c = -2$$

(C) Area = 

$$\text{Area R} = \int_{1/2}^1 (x^3 - 3x^2 + 2x) dx$$

$$= \frac{1}{2} \times \frac{3}{2} \times \frac{3}{8} - \left[ \frac{1}{4} x^4 - x^3 + x^2 \right]_{1/2}^1$$

$$= \frac{9}{32} - \left[ \left( \frac{1}{4} \right) - \left( \frac{9}{64} \right) \right]$$

$$= \frac{9}{32} - \frac{7}{64} = \frac{11}{64}$$

(Total 2 marks)

Q#6

