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JUNE 2007 TEST
COURSE AND CODE: FOUNDATION MATHEMATICS (MATH 099/199)

QUESTION ONE [17 marks]

(a) True or False? All natural numbers are rational numbers. (WITH REASON) (1)

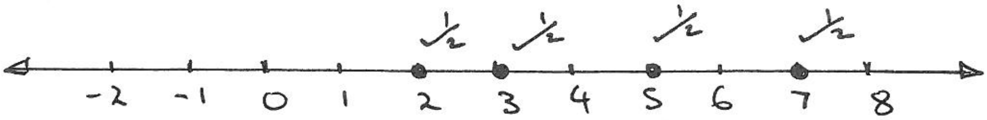
TRUE ✓½ SINCE $\mathbb{N} \subset \mathbb{Q}$ ✓½.

(b) Let M be a set of real numbers between -6 and 10. Illustrate on separate number lines, the set of all elements in M that are:

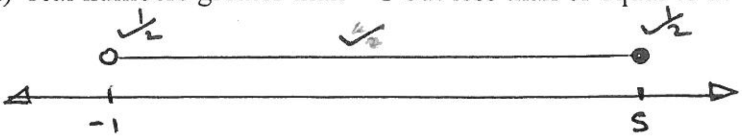
(i) negative integers. (2)

$-\frac{1}{2}$ FOR EACH WRONG ELEMENT up to 0.

(ii) prime numbers. (2)



(iii) real numbers greater than -1 but less than or equal to 5. (2)



(c) Define a rational number and hence, show that $0.58\dot{3}$ is a rational number. (5)

A RATIONAL NUMBER IS A NUMBER WHICH CAN BE WRITTEN IN THE FORM $\frac{a}{b}$, $a, b \in \mathbb{Z}$, $b \neq 0$. ✓

LET $x = 0.58333\ldots$ (1) ✓½

THEN $10x = 5.83333\ldots$ (2) ✓½

(2) − (1) $9x = 5.25$ ✓

$\therefore x = \frac{5.25}{9} = \frac{525}{900} = \frac{21}{36}$ ✓ WHICH IS OF THE FORM OF A RATIONAL NUMBER.

HENCE $0.58\dot{3}$ IS RATIONAL. ✓

(d) Prove that the product of two odd numbers is an odd number. (5)

LET $a, b \in \mathbb{Z}$ ✓½

THEN $a = 2m+1$ ✓½ AND $b = 2n+1$ ✓½ ARE ODD, $m, n \in \mathbb{Z}$

NOW,

$$ab = (2m+1)(2n+1) \checkmark$$
$$= 4mn + 2m + 2n + 1$$
$$= 2(2mn + m + n) + 1 \checkmark\tfrac{1}{2}$$
$$= 2k + 1 \checkmark \quad \text{WHERE } 2mn + m + n = k,\ k \in \mathbb{Z} \checkmark$$

HENCE, THE PRODUCT OF TWO ODD NUMBERS IS AN ODD NUMBER.

QUESTION TWO [18 marks]

(a) Let B be any non-empty set, and A be a subset of B.
True or False? If false, give the correct answer:

(i) $A \cup A' = \{\}$ (2)

FALSE, ✓ SINCE $A \cup A' = B$ ✓

(ii) $A \cap \{\ \} = B$ (2)

FALSE. ✓

$A \cap \{\} = \{\}$ ✓

(b) Consider the following sets of different make of motor vehicles which were recently auctioned by the Department of Transport, where E is the universal set.

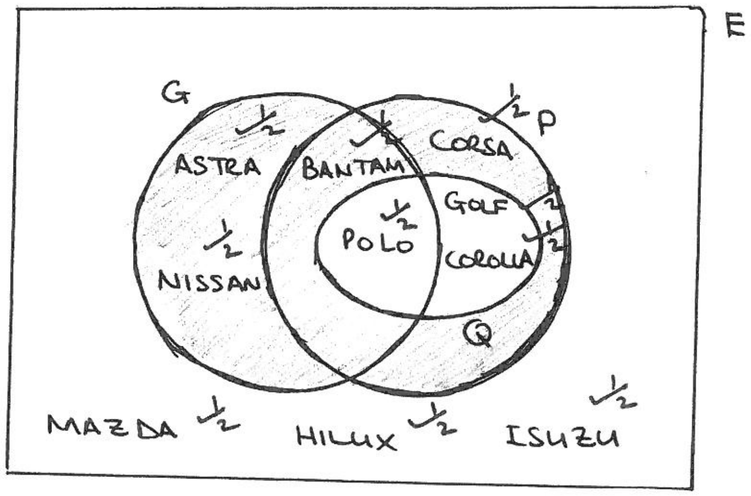
$E = \{$ Corsa, Polo, Corolla, Mazda, Astra, Golf, Hilux, Nissan, Isuzu, Bantam $\}$

$G = \{$ Astra, Polo, Nissan, Bantam $\}$

$P = \{$ Bantam, Corolla, Polo,Golf, Corsa $\}$

$Q = \{$ Golf, Polo, Corolla $\}$

(i) Draw a Venn diagram, showing all the sets given above, and put the elements in their correct places. (5)



(ii) Determine:

$(Q \cap P)' \cap G$ (3)

= { ASTRA ; NISSAN ; BANTAM } $-\frac{1}{2}$ FOR INCORRECT BRACKETS

(iii) Determine:

$n\ (G \cup G')$ (3)

$= n(\{$ E $\}) = 10$

(iv) On your Venn diagram in Question b(i) above, shade $Q' \cap (G \cup P)$. (3)

SEE ABOVE

SHADED : G ✓
P ✓
Q' ✓

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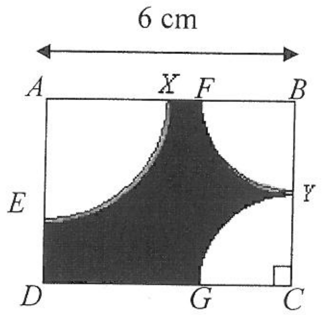
QUESTION THREE [28 marks]

(a) In the diagram below, all curved lines are arcs of circles. $ABCD$ is a rectangle with $AB = 6$ cm, $AX = XB$ and $BY = YC = 2$ cm. Determine the perimeter of the shaded region. (6)



$AX = XB = \frac{6}{2} = 3\text{cm}$ ✓½

$BY = YC = 2\text{ cm}$ ∴ $BC = AD = 4\text{cm}$ ✓½

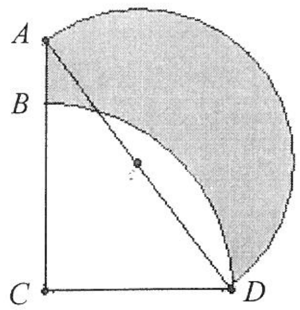
✓½

PERIMETER OF SHADED REGION $= \overset{\frown}{EX} + XF + \overset{\frown}{FY} + \overset{\frown}{YG} + GD + D$

$= \frac{1}{4}(2\pi \times 3)$ ✓½ $+ (6-3-2)$ ✓½ $+ \frac{1}{4}(2\pi \times 2)$ ✓½ $+ \frac{1}{4}(2\pi \times 2)$ ✓½ $+ (6-2)$ ✓½ $+ (4-3$ ✓½

$= \frac{3\pi}{2} + 1 + \pi + \pi + 4 + 1$

$= \left(\frac{7\pi}{2} + 6\right)$ ✓½ ✓½ cm ✓½ UNITS (b).



In the diagram alongside,

- ACD is a right-angled triangle.
- $AC = 28$ cm and $BC = 21$ cm.
- A semicircle is drawn using AD as diameter.
- Sector BCD has CD as radius.

Determine the area of the shaded region.
Leave your answer in terms of π. (7)

AREA OF SHADED REGION = AREA Δ ACD + AREA $\frown$ AD − SECTOR BCD

$$= \left(\tfrac{1}{2} \times 28 \times 21\right) + \tfrac{1}{2}\pi\left(\tfrac{AD}{2}\right)^2 - \tfrac{1}{4}\left(\pi \times [21]^2\right)$$

$$= \left(294 + \tfrac{\pi}{8} \times (AD)^2 - \tfrac{441}{4}\pi\right) \text{ cm}^2$$

BUT $(AD)^2 = (AC)^2 + (CD)^2$ (PYTHAGORAS)

$$= (28)^2 + (21)^2$$

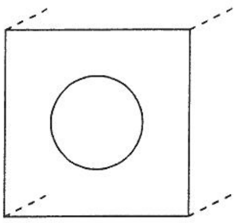
$$= 1225 \text{ cm}^2$$

$\therefore$ AREA OF SHADED REGION $= \left(294 + \tfrac{\pi}{8} \times 1225 - \tfrac{441}{4}\pi\right) \text{cm}^2$

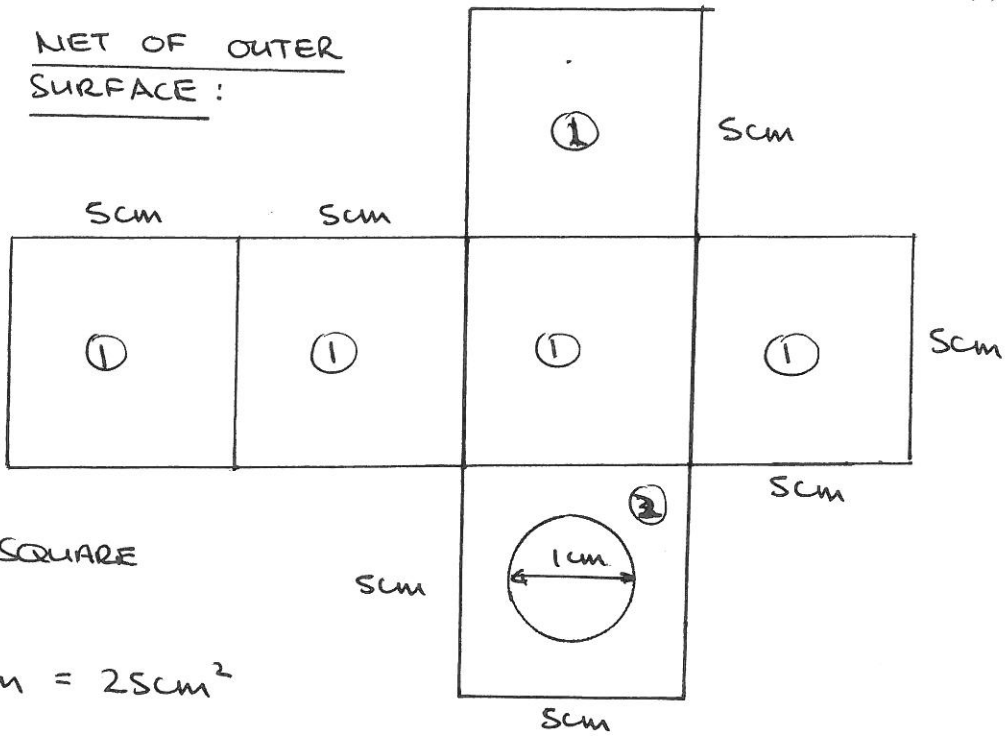
$$= \left(294 + \frac{343\pi}{8}\right) \text{cm}^2$$ UNITS

$42\frac{7}{8}$

(c). A solid wooden cube has side of length 5 cm. A circular hole of diameter 1 cm is drilled through **one of the faces of the wooden cube** as shown below. The hole is 2 cm deep. Determine the total surface area of the wooden cube. (8)



NET OF OUTER SURFACE:



AREA 1 = AREA OF SQUARE

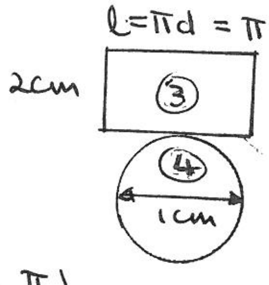
$= 5 \times 5$

$= 5cm \times 5cm = 25cm^2$

AREA 2 = AREA OF SQUARE − AREA OF CIRCLE

$= (5 \times 5) - \pi r^2$

$= (5 \times 5) - \pi(\frac{1}{2})^2 = (25 - \frac{\pi}{4})\ cm^2$



NET OF HOLE

AREA 3 = AREA OF RECTANGLE = LENGTH × BREADTH

$= \pi \times 2 = 2\pi$ cm

AREA 4 = AREA OF CIRCLE

$= \pi r^2 = \pi(\frac{1}{2})^2 = \frac{\pi}{4}\ cm^2$

TOTAL SURFACE AREA $= (5 \times \text{AREA } 1) + \text{AREA } 2 + \text{AREA } 3 + \text{AREA } 4$

$= (5 \times 25) + (25 - \frac{\pi}{4}) + 2\pi + \frac{\pi}{4}$

$= 125 + 25 + 2\pi$

½ UNITS

$= (150 + 2\pi)\ cm^2$

* Ratio Det $y:b$

$xy = ab$

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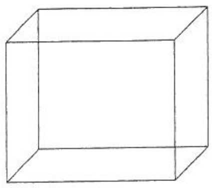
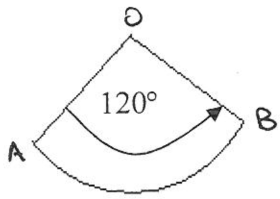
(d). 

Prism 1



Cross Section of Prism 2

Prism 1, which is a rectangular prism, has a length of $2x$ mm, a breadth of x mm and a height of h_1 mm.
Prism 2, whose cross section is a sector with radius x mm, has angle AOB $= 120^0$.

Prism 1 is completely full of water. All the water from prism 1 is then poured into prism 2.
The water level in prism 2 is h_2 mm.

Determine $h_2 : h_1$. (7)

VOLUME OF PRISM 1 = AREA OF BASE × HEIGHT OF PRISM

$= (\text{LENGTH} \times \text{BREADTH}) \times \text{HEIGHT}$

$= (2x \times x) \times h_1 = 2x^2 h_1 \text{ mm}^3$ (1)

VOLUME OF PRISM 2 = AREA OF BASE × HEIGHT OF PRISM

$=$ AREA OF SECTOR × HEIGHT

$= \dfrac{120^0}{360} \times \pi x^2 \times h_2 = \dfrac{\pi x^2}{3} \cdot h_2 \text{ mm}^3$ (2)

BUT THE VOLUMES ARE EQUAL

$\therefore \dfrac{\pi x^2}{3} h_2 = 2x^2 h_1$ (1)

$\dfrac{h_2}{h_1} = \dfrac{2x^2}{1} \times \dfrac{3}{\pi x^2} = \dfrac{6}{\pi}, \ (x \neq 0)$

$\therefore h_2 : h_1 = 6 : \pi$

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QUESTION FOUR [16 marks]

(a).State the type of proportion between x and y , in each of the following (give a reason in each case) :

(i)

x	2	4	- 8
y	3	6	- 12

(2)

$\frac{2}{3} = \frac{4}{6} = \checkmark\tfrac{1}{2}\ \frac{-8}{-12} \checkmark\tfrac{1}{2}$

$\therefore$ DIRECT PROPORTION ✓

(ii)

x	1	3	5
y	2	4	6

$\frac{1}{2} \neq \frac{3}{4} \neq \frac{5}{6} \checkmark\tfrac{1}{2}$ AND $1 \times 2 \neq 3 \times 4 \neq 5 \times 6 \checkmark\tfrac{1}{2}$ (2)

$\therefore$ NO PROPORTION ✓

(iii)

x	- 1	- 4	- 6
y	12	3	2

(2)

$-1 \times 12 = -4 \times 3 = \checkmark\tfrac{1}{2}\ -6 \times 2 \checkmark\tfrac{1}{2}$

$\therefore$ INVERSE PROPORTION ✓

(b). Jane is 25 years younger than her mother. In 12 years time she will be half her mothers' age. Calculate Jane's age, by making use of suitable equations: (5)

JANES AGE	MOTHERS AGE
x ✓½	$x+25$ ✓
$x+12$ ✓½	$x+37$ ✓

LET JANES AGE BE x $\therefore$

IN TWELVE YEARS

$x + 12 = \frac{1}{2}(x + 37) \checkmark\tfrac{1}{2}$

$\therefore 2x + 24 = x + 37 \checkmark\tfrac{1}{2}$

$x = 13$ $\therefore$ JANE IS 13 YEARS OLD ✓

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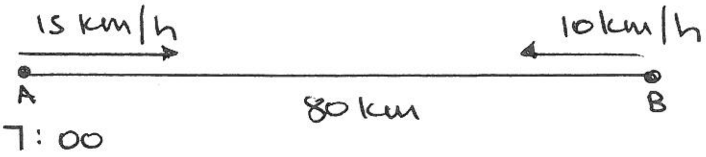
....

(c). Two cyclists are 80 km apart and travel towards each other. They start at 7 :00 and cycle at a constant speed of 15 km/h and 10 km/h. By using suitable equations determine at what time the cyclists will meet. (5)



$\text{SPEED} = \dfrac{\text{DISTANCE}}{\text{TIME}}$ ✓ $\therefore$ IN t HOURS THE DISTANCE TRAVELLED IS :

$$15t + 10t = 80\text{km} ✓$$
$$25t = 80$$
$$t = 3\tfrac{1}{5}\text{ hr} ✓ = 3\text{h } 12\text{ min} ✓$$

$\therefore$ TIME OF MEETING $=$ 7h 00min $+$ 3h 12min $=$ 10 : 12 ✓

QUESTION FIVE [6 marks]

(a). Determine the solution of the following system of equations :

$$\begin{aligned} x + 2y - z &= 1 \\ 5x - y + 2z &= 5 \\ 2x + 4y - 2z &= 2 \end{aligned}$$ (6)

$$\left[\begin{array}{ccc|c} 1 & 2 & -1 & 1 \\ 5 & -1 & 2 & 5 \\ 2 & 4 & -2 & 2 \end{array}\right] \begin{array}{l} \cdots\cdots(A) \\ \cdots\cdots(B) \\ \cdots\cdots(C) \end{array} \longrightarrow \left[\begin{array}{ccc|c} 1 & 2 & -1 & 1 \\ 0 & 11 & -7 & 0 \\ 0 & 0 & 0 & 0 \end{array}\right] \begin{array}{l} \\ ✓ (5\times A) - B \\ ✓ (2\times A) - C \end{array}$$

LET $z = t$ ✓, $t \in \mathbb{R}$ $\tfrac{1}{2}$✓

$\therefore$ $11y - 7z = 0$

$11y - 7t = 0$ $\therefore$ $y = \dfrac{7t}{11}$ ✓

$x + 2y - z = 1$

$x + 2\left(\dfrac{7t}{11}\right) - t = 1$ $\therefore$ $x = 1 - \dfrac{14t}{11} + t$

$x = 1 - \dfrac{3t}{11}$ ✓

Solution $= \left\{(x, y, z) \in \mathbb{R}^3, t \in \mathbb{R} : \left(1 - \dfrac{3t}{11}, \dfrac{7t}{11}, t\right)\right\}$

$\tfrac{1}{2}$✓

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QUESTION SIX [12 marks]

(a) Solve for x and illustrate your solution graphically:

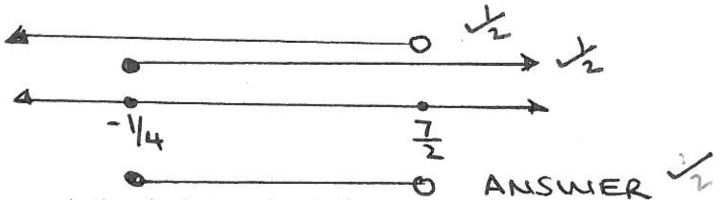
$$-x+1 \le \frac{3+2x}{2} < 5 \qquad (5)$$

$-x+1 \le \frac{3+2x}{2}$ ✓½ ✓½ AND $\frac{3+2x}{2} < 5$ ✓½

$-2x+2 \le 3+2x$ ✓½ AND $3+2x < 10$ ✓½

$-4x \le 1$ AND $2x < 7$

$x \ge -\frac{1}{4}$ ✓½ AND $x < 7/2$ ✓½



(b) Solve for x and write your solution in interval notation:

$$\frac{1}{x-3} \le \frac{9}{4x+3} \qquad (7)$$

$\frac{1}{x-3} \le \frac{9}{4x+3}$

$\frac{1}{x-3} - \frac{9}{4x+3} \le 0$ ✓

$\frac{4x+3-9(x-3)}{(x-3)(4x+3)} \le 0$

$\frac{4x+3-9x+27}{(x-3)(4x+3)} \le 0$

$\frac{-5x+30}{(x-3)(4x+3)} \le 0$

$\frac{-5(x-6)}{(x-3)(4x+3)} \le 0$ ✓½ ✓½ ✓½ — (A)

CRITICAL VALUES : ✓½ $-\frac{3}{4}$ ✓½ ; 3 ; 6 ✓½

RESTRICTIONS : $x \ne 3$ ✓½ ; $x \ne -\frac{3}{4}$ ✓½

		$-\frac{3}{4}$		3		6	
-5	−	−	−	−	−	−	−
$(x-6)$	−	−	−	−	−	0	+
$(x-3)$	−	−	−	0	+	+	+
$(4x+3)$	−	0	+	+	+	+	+
$\frac{-5(x-6)}{(x-3)(4x+3)}$	+	UD	−	UD	+	0	−

WE NEED TO FIND VALUES FOR x FOR WHICH THE FRACTION (A) IS ≤ 0

$\therefore\ x \in (-\frac{3}{4}; 3) \cup [6; \infty)$ ✓½ ✓½ ✓½ ✓½

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QUESTION SEVEN [14 marks]

(a) Find the domain, in set-builder notation, of the following function:

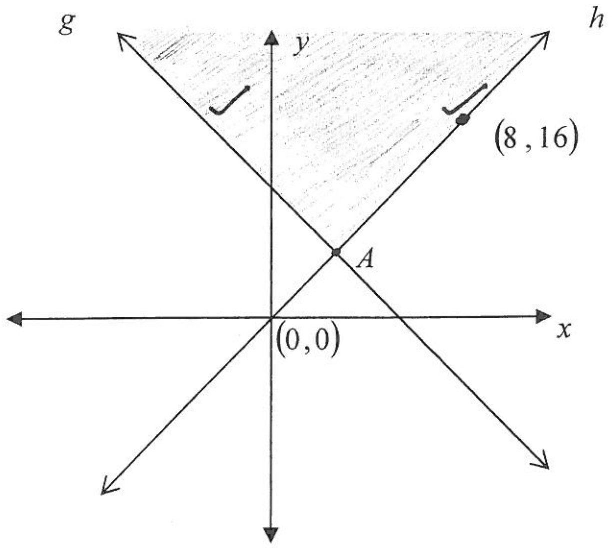
$$f(x) = \frac{1}{\sqrt{2 - x}} \qquad (3)$$

D_f : $2 - x > 0$ ✓½ ✓½

$x < 2$ ✓

DOMAIN $= \{ x \in \mathbb{R} \mid x < 2 \}$ ✓½ ✓½

(c) The graphs of $g(x) = -x + 6$ and $h(x)$ are illustrated on the diagram below:



(i) Determine the equation of h. (3)

GRADIENT / SLOPE OF h :

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{16 - 0}{8 - 0} = 2$ ✓½ ✓½

$\therefore h = mx + c$

$\therefore h = 2x + c$

POINT $(0;0)$ GIVES :

$0 = 2(0) + c$

$\therefore c = 0$ ✓

$\therefore h(x) = 2x$ ✓

(ii) Determine the co-ordinates of point A, ie. the point of intersection of g and h. (2)

AT THE POINT OF INTERSECTION

$h(x) = g(x)$ ✓

$\therefore 2x = -x + 6$

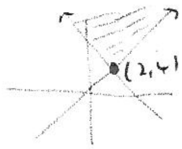
$3x = 6$

$\therefore x = 2$ ✓½

SUBSTITUTE $x = 2$ INTO h (OR g)

$h(x) = 2x \quad \therefore h(2) = 2(2) = 4$ ✓½

$\therefore$ Pt. A IS $(2;4)$



(iii) Shade the region represented by $\{y \geq g\} \cap \{y \geq h\}$ (2)

SEE DIAGRAM

(iv) Show that $(g^{-1} \circ g)(x) = (g \circ g^{-1})(x) = x$ (4)

$g(x) = -x + 6$

$g^{-1}(x) = -x + 6$ ✓

LHS: $(g^{-1} \circ g)x = g^{-1}(g(x))$ ✓½ $= g^{-1}(-x+6)$ ✓½

$= -(-x+6) + 6$

$= x - 6 + 6$

$= x$ ✓½

RHS: $(g \circ g^{-1})(x) = g(g^{-1}(x))$ ✓½

$= g(-x+6)$ ✓½

$= -(-x+6) + 6$

$= x - 6 + 6$

$= x$ ✓½

$=$ LHS

$\therefore (g^{-1} \circ g)(x) = (g \circ g^{-1})(x) = x$

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QUESTION EIGHT [12 marks]

Given the following quadratic equation:

$$f(x) = 3x^2 + 2x - 1$$

(a) Write $f(x)$ in the form $y = a(x-p)^2 + q$. (3)

$$f(x) = 3x^2 + 2x - 1$$
$$= 3\left[x^2 + \frac{2x}{3} - \frac{1}{3}\right] \checkmark\tfrac{1}{2}$$
$$= 3\left[x^2 + \frac{2}{3}x + \frac{1}{9} - \frac{4}{9} - \frac{1}{3}\right]$$
$$= 3\left[\left(x + \frac{1}{3}\right)^2 - \frac{4}{9}\right] \checkmark\tfrac{1}{2}$$
$$\therefore f(x) = \overset{\checkmark\frac{1}{2}}{3}\left(x + \overset{\checkmark\frac{1}{2}}{\frac{1}{3}}\right)^2 - \frac{4}{3} \checkmark\tfrac{1}{2}$$

(b) Find the equation of the inverse of $f(x)$. (3)

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

CAN BE WRITTEN AS $y = 3\left(x + \frac{1}{3}\right)^2 - \frac{4}{3}$

INTERCHANGING x AND y GIVES

$$\overset{\checkmark\frac{1}{2}}{x} = 3\left(\overset{\checkmark\frac{1}{2}}{y} + \frac{1}{3}\right)^2 - \frac{4}{3}$$
$$x + \frac{4}{3} = 3\left(y + \frac{1}{3}\right)^2$$
$$\frac{x}{3} + \frac{4}{9} = \left(y + \frac{1}{3}\right)^2 \checkmark\tfrac{1}{2}$$
$$\therefore y + \frac{1}{3} = \pm\sqrt{\frac{x}{3} + \frac{4}{9}}$$
$$y = \overset{\checkmark\frac{1}{2}}{-\frac{1}{3}} \overset{\checkmark\frac{1}{2}}{\pm} \sqrt{\frac{x}{3} + \frac{4}{9}} \checkmark\tfrac{1}{2}$$

WHICH IS THE INVERSE OF $f(x)$

(c) Write down the greatest restriction of $f(x)$, called $g(x)$, so that the inverse of $g(x)$, is a function. (2)

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

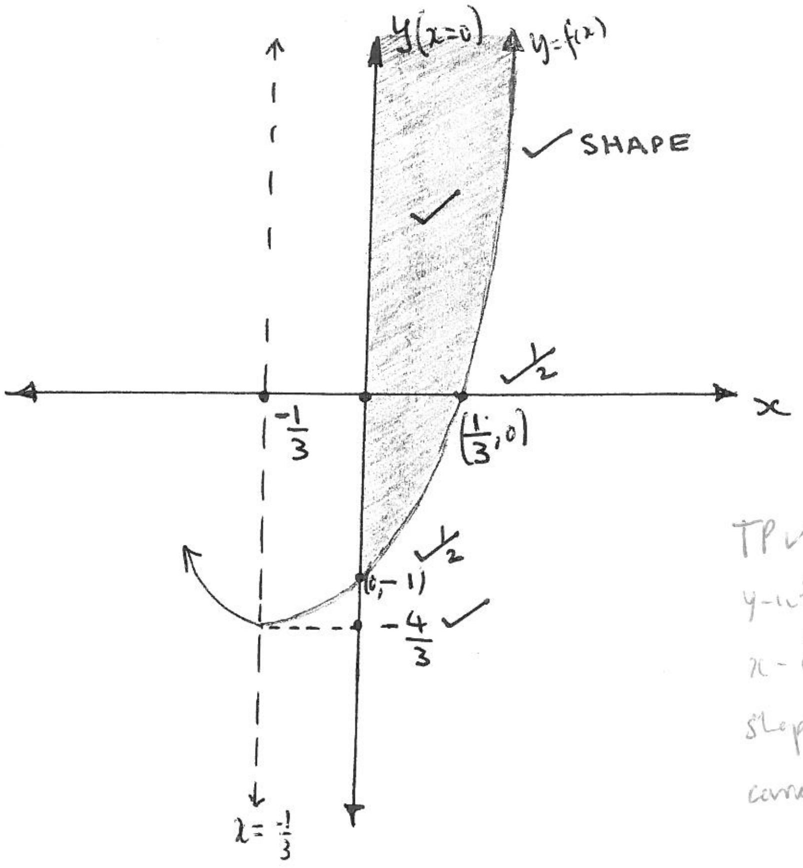
$\therefore$ AXIS OF SYMMETRY IS $x = -\frac{1}{3}$

$\therefore \quad g(x) = 3x^2 + 2x - 1$ ✓, $x \leq -\frac{1}{3}$ ✓

<u>OR</u> $g(x) = 3x^2 + 2x - 1$, $x \geq -\frac{1}{3}$

(d) Sketch the region defined by:

$$A = \{(x;y) \in R^2 \mid \ x \geq 0 \ \} \cap \{(x;y) \in R^2 \mid \ y \geq f(x)\}$$ (4)



TP ✓
y-int ½
x-int ½
shape ✓
correct region ✓

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QUESTION NINE [27 marks]

(a) State if the following are **TRUE** or **FALSE.**

(i) A circle is a function. (1)

FALSE ✓

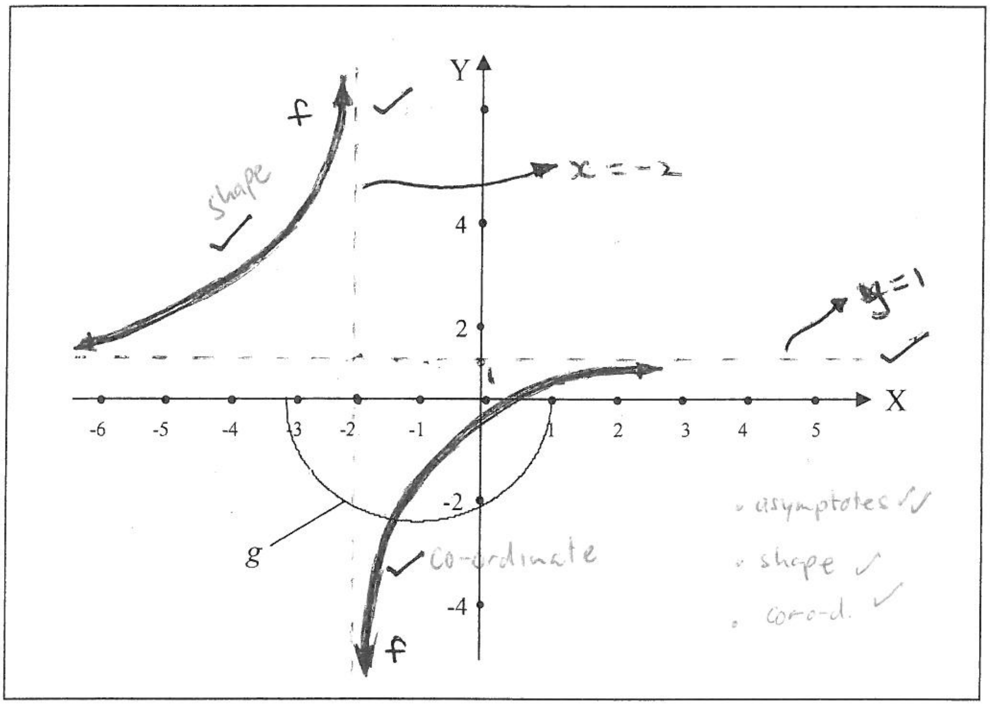
(ii) The hyperbola of the form $y = \frac{k}{x}$ must be restricted for its inverse to be a function. (1)

FALSE ✓

(b) The general equation of a hyperbola is $y = \frac{k}{x}$. Explain what **effect** the constant k, has on the shape of graph of a hyperbola. (2)

THE LARGER ✓ THE VALUE OF k, THE FURTHER ✓ AWAY FROM THE ORIGIN THE GRAPH IS.

(c) Study the graph sketched below carefully and answer the questions that follow.



(i) Write down the equation of the graph g, sketched above. (4)

$$g(x) = -\sqrt{-(x+1)^2 + 4}$$

(ii) Write down the domain of the inverse of g. (2)

$$D(g^{-1}) = \{x \in \mathbb{R} \mid -2 \le x \le 0\}$$

OR

$$[-2;0]$$

(iii) If the graph of g is reflected about the line $y = -x$, determine the new equation of g. (3)

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

$$\therefore -x = -\sqrt{-(-y+1)^2 + 4}$$

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

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

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

$$-y+1 = \pm\sqrt{4 - x^2}$$

$$y = 1 \pm \sqrt{4 - x^2}, \quad 0 \le x \le 2$$

(d) On the axis above (on which the graph of g is sketched) :

(i) Sketch the graph of the equation $(x+2)(y-1)=-3$. Call this new graph f. (4)

SEE DIAGRAM

(e) A circle with equation $x^2+y^2+6x-4y=k$ has a radius of 4 *units.*

(i) Calculate the coordinates of the centre of the circle. (3)

$(x^2+6x)+(y^2-4y)=k$

$(x^2+6x+3^2-3^2)+(y^2-4y+(-2)^2-(-2)^2)=k$

$(x^2+6x+9)+(y^2-4y+4)=k+9+4$

$(x+3)^2+(y-2)^2=k+9+4$

CIRCLE CENTRE IS $(-3;2)$

(ii) Hence, determine k. (2)

$k+9+4=(\text{RADIUS})^2=(4)^2=16$

$\therefore\ k=16-9-4=3\text{ UNITS}^2$

(f) The graph of $f(x)=ax^2+bx+c$, where $a\neq 0$, has the following properties:

- Passes through the point (0, 4).
- Has axis of symmetry $x=-2$.
- Has a maximum value of 10.

$y=a(x+2)^2+10$

$a=\frac{-6}{4}$

Determine a, b and c. (5)

$f(x)=ax^2+bx+c$

PASSES THROUGH $(0;4)$

$\therefore\ 4=a(0)^2+b(0)+c$

$c=4$

AXIS OF SYMMETRY

$x=-2=-\frac{b}{2a}$

$\therefore\ -b=-4a$

$b=4a$

MAXIMUM VALUE OF 10

$\therefore$ TURNING POINT IS $(-2;10)$

$10=a(-2)^2+b(-2)+4$

$10=4a-2b+4$

$10=4a-2(4a)+4$ (SUB. $b=4a$)

$10=4a-8a+4$

$-4a=6 \quad \therefore\ a=\frac{-6}{4}$

$\therefore\ b=4a$ GIVES $b=4\left(\frac{-6}{4}\right)$

$b=-6$