SYDNEY BOYS HIGH SCHOOL
MOORE PARK, SURRY HILLS

2008
TRIAL
HIGHER SCHOOL CERTIFICATE

Mathematics Extension 1

General Instructions

- Reading Time – 5 Minutes
- Working time – 2 Hours
- Write using black or blue pen. Pencil may be used for diagrams.
- Board approved calculators may be used.
- Start each question in a new booklet
- The questions are of equal value
- Marks may NOT be awarded for messy or badly arranged work.
- All necessary work should be shown in every question.
- Full marks will NOT be given unless the method of the solution is shown.

Total Marks – 84

- Attempt all questions

Examiner: *R. Boros*

This is an assessment task only and does not necessarily reflect the content or format of the Higher School Certificate

STANDARD INTEGRALS

$$\int x^n dx = \frac{1}{n+1} x^{n+1}, \ n \neq -1; \ x \neq 0, \text{if } n < 0$$

$$\int \frac{1}{x} dx = \ln x, \ x > 0$$

$$\int e^{ax} dx = \frac{1}{a} e^{ax}, \ a \neq 0$$

$$\int \cos ax \, dx = \frac{1}{a} \sin ax, \ \ a \neq 0$$

$$\int \sin ax \, dx = -\frac{1}{a} \cos ax, \ \ a \neq 0$$

$$\int \sec^2 ax \, dx = \frac{1}{a} \tan ax,$$

$$\int \sec ax \tan ax \, dx = \frac{1}{a} \sec ax, \ \ a \neq 0$$

$$\int \frac{1}{a^2 + x^2} dx = \frac{1}{a} \tan^{-1} \frac{x}{a}, \ \ a \neq 0$$

$$\int \frac{1}{\sqrt{a^2 - x^2}} dx = \sin^{-1} \frac{x}{a}, \ \ a > 0, \ \ -a < x < a$$

$$\int \frac{1}{\sqrt{x^2 - a^2}} dx = \ln\left(x + \sqrt{x^2 - a^2} \right), \ x > a > 0$$

$$\int \frac{1}{\sqrt{x^2 + a^2}} dx = \ln\left(x + \sqrt{x^2 + a^2} \right)$$

NOTE: $\ln x = \log_e x, \ \ x > 0$

Start each question in a new answer booklet.

Question 1 (12 marks). **Marks**

a) Find the acute angle between the intersection of the curves $y = x^2 + 4$ and $y = x^2 - 2x$, correct to the nearest minute. 2

b) A is the point (-4, 2) and B is the point (3, -1). Find the coordinates of the point P which divides the interval AB externally in the ratio 2:1 2

c) Differentiate $y = \log_e\left(\sin^{-1} x\right)$ 2

d) Solve the inequality $\dfrac{x-1}{x+3} \geq -2$ 2

e) If $\cos A = \dfrac{7}{9}$ and $\sin B = \dfrac{1}{3}$ where A and B are acute angles,

Prove that $A = 2B$. 2

f) Use the substitution $u = t + 1$ to evaluate $\displaystyle\int_0^1 \frac{t}{\sqrt{t+1}}\,dt$ 2

End of Question 1.

Start a new booklet.

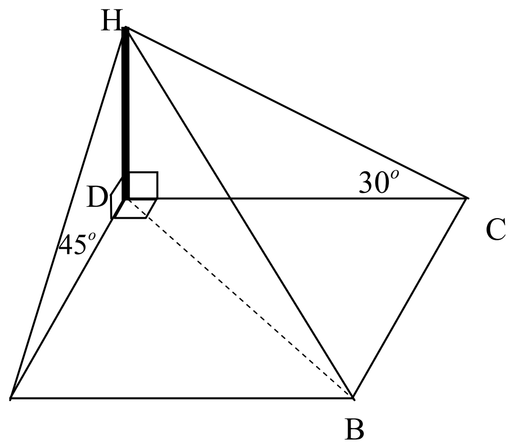
Question 2 (12 Marks). **Marks**

a) The polynomial $P(x)=ax^3+bx^2-8x+3$ has a factor of $(x-1)$ and leaves a remainder of 15 when divided by $(x+2)$. Find the values of a and b and hence fully factorise $P(x)$. 3

b) (i) Express $3\sin\theta+2\cos\theta$ in the form $R\sin(\theta+\alpha)$ where α is an acute angle.

(ii) Hence, or otherwise solve the equation $3\sin\theta+2\cos\theta=2.5$ for $0^\circ\le\theta\le 360^\circ$. Answer correct to the nearest minute. 4

c) A post HD stands vertically at one corner of a rectangular field $ABCD$ The angle of elevation of the top of the post H from the nearest corners A and C are 45^o and 30^o respectively.



(i) If $AD=a$ units, find the length of BD in terms of a 2

(ii) Hence, find the angle of elevation of H from the corner B to the nearest minute. 1

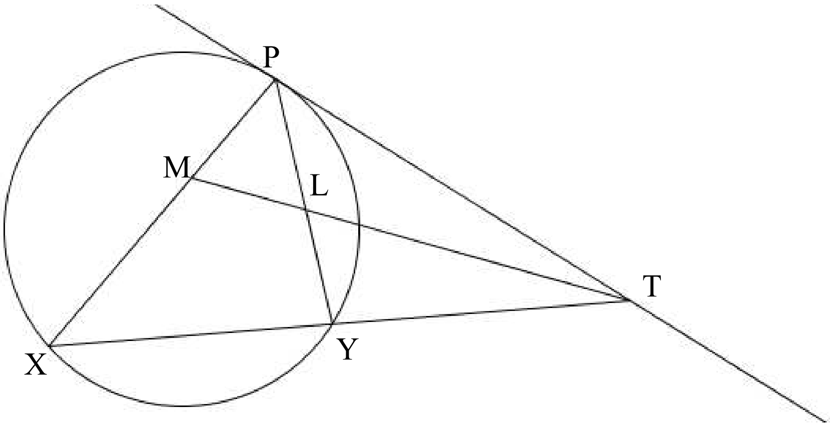
d) Taking $x=\dfrac{-\pi}{6}$ as a first approximation to the root of the equation $2x+\cos x=0$, use Newton's method once to show that a second approximation to the root of the equation is $\dfrac{-\pi-6\sqrt{3}}{30}$. 2

End of Question 2.

Start a new booklet.

Question 3 (12 marks). **Marks**

a) Diagram not to scale.



XY is any chord of a circle. XY is produced to T and TP is a tangent to the circle. The bisector of $\angle PTX$ meets XP in M and cuts PY at L. Prove that $\triangle MPL$ is isosceles. 3

b) (i) Find the domain and range of $f^{-1}(x) = \sin^{-1}(3x - 1)$. 2

(ii) Sketch the graph of $y = f^{-1}(x)$. 1

(iii) Find the equation representing the inverse function $f(x)$ and state the domain and range. 3

c) Newton's Law of Cooling states that the rate of cooling of a body is proportional to the excess of the temperature of a body above the surrounding temperature. This rate can be represented by the differential equation $\frac{dT}{dt} = -k(T - T_0)$, where T is the temperature of the body, T_0 is the temperature of the surroundings, t is the time in minutes and k is a constant.

(i) Show that $T = T_0 + Ae^{-kt}$, where A is a constant, is a solution to the differential equation $\frac{dT}{dt} = -k(T - T_0)$. 1

(ii) A cup of coffee cools from $85^{o}C$ to $80^{o}C$ in one minute in a room temperature of $25^{o}C$. Find the temperature of the cup of coffee after a further 4 minutes have elapsed. Answer to the nearest degree. 2

End of Question 3.

Start a new booklet.

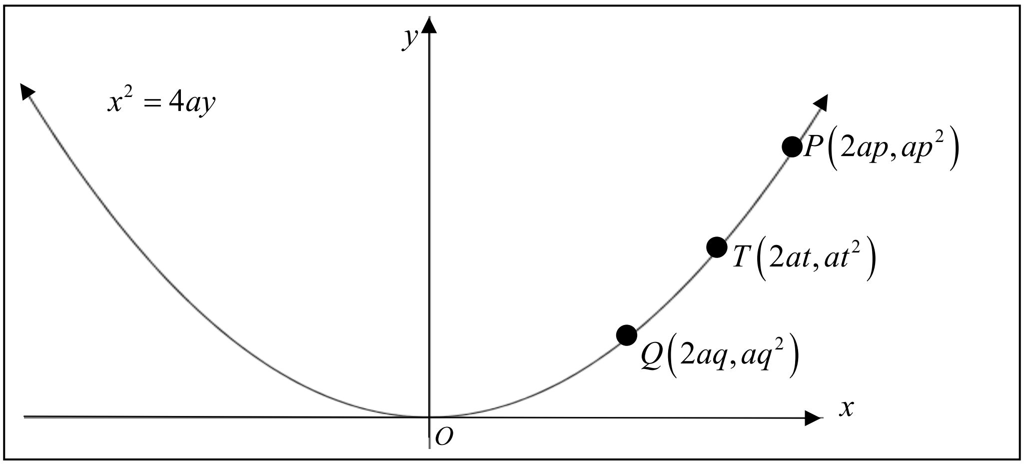
Question 4 (12 marks). **Marks**

a) Find the number of ways of seating 5 boys and 5 girls at a round table if:

(i) A particular girl wishes to sit between two particular boys. 1

(ii) Two particular persons do not wish to sit together. 1

b) $P\left(2ap, ap^2\right)$ and $Q\left(2aq, aq^2\right)$ are the points on the parabola $x^2 = 4ay$



It is given that the chord PQ has the equation $y - \frac{1}{2}(p+q)x + apq = 0$

(i) Derive the equation of the tangent to the parabola $x^2 = 4ay$ at the point $T\left(2at, at^2\right)$. 2

(ii) The tangent at T cuts the y-axis at the point R. Find the coordinates of the point R. 1

(iii) If the chord PQ passes through the point R show that p, t and q are terms of a geometric series. 2

c) A particle moves so that its distance x cm from a fixed point O at time t seconds is $x = 2\cos 3t$.

(i) Show that the particle satisfies the equation of motion $\ddot{x} = -n^2 x$ where n is a constant. 2

(ii) What is the period of the motion? 1

(iii) What is the velocity when the particle is first 1cm from O. 2

End of Question 4.

Start a new booklet.

Question 5 (12 marks). **Marks**

a) Find the general solution of the equation $\tan\theta = \sin 2\theta$ 3

b) The cubic equation $2x^3 - x^2 + x - 1 = 0$ has roots α, β and γ. Evaluate

(i) $\alpha\beta + \beta\gamma + \alpha\gamma$ 1

(ii) $\alpha\beta\gamma$ 1

The equation $2\cos^3\theta - \cos^2\theta + \cos\theta - 1 = 0$ has roots $\cos a$, $\cos b$ and $\cos c$.

Using appropriate information from parts (i) and (ii), prove that 2

$\sec a + \sec b + \sec c = 1$.

c) (i) Sketch the curve $y = 2\cos x - 1$ for $-\pi \le x \le \pi$. Mark clearly where the graph crosses each axis. 2

(ii) Find the volume generated by the rotation through a complete revolution about the x axis of the region between the x-axis and that part of the curve $y = 2\cos x - 1$ for which $|x| \le \pi$ and $y \ge 0$ 3

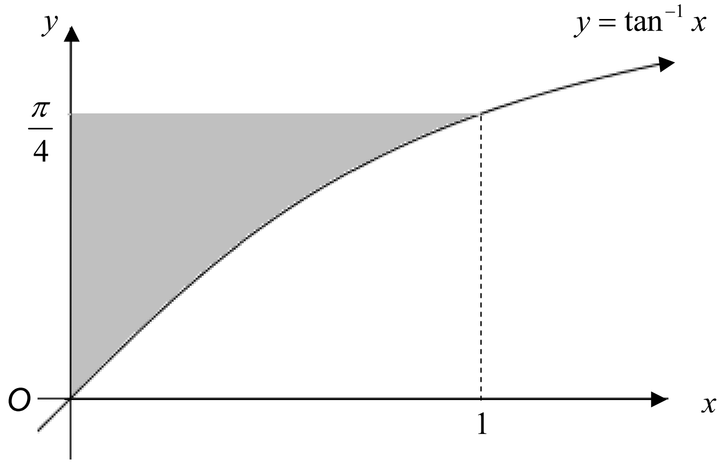
End of Question 5

Start a new booklet.

Question 6 (12 marks). **Marks**

a) (i) Find $\frac{d}{dy}\left(\ln \cos y\right)$. 1

(ii)



Show that the shaded area is given by $A = \frac{1}{2}\ln 2$ units^2 3

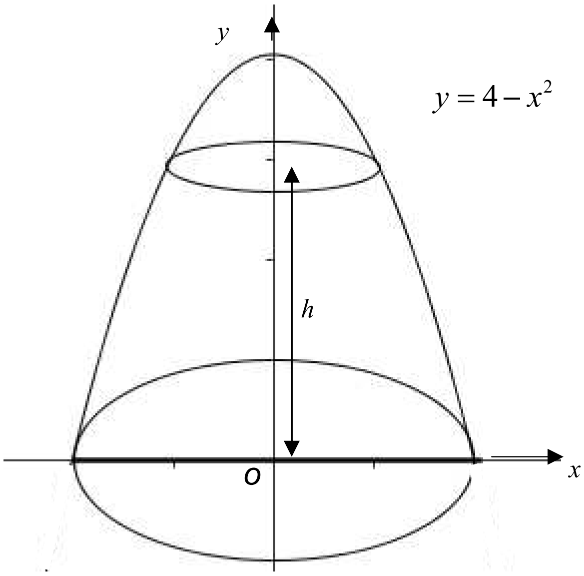
b) *P, Q, R* and *S* are four points taken in order on a circle. Prove that:

$$\frac{PR}{QS} = \frac{\sin P\hat{Q}R}{\sin Q\hat{P}S}$$ 3

Question 6 continued next page.

Question 6 continued

c)



A mould for a container is made by rotating the part of the curve $y = 4 - x^2$ which lies in the first quadrant through one complete revolution about the *y*-axis. After sealing the base of the container, water is poured through a hole in the top. When the depth of water in the container is *h* cm, the depth is changing at a rate of $\dfrac{10}{\pi(4-h)}$ cms^{-1}.

(i) Show that when the depth is *h* cm, the surface area *S* cm^2 of the top of the water is given by $S = \pi(4-h)$. 2

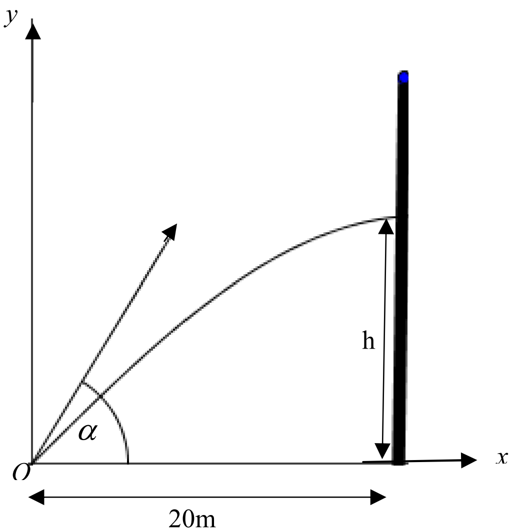
(ii) Find the rate at which the surface area of the water is changing when the depth of the water is 2cm. 3

End of Question 6.

Start a new booklet.

Question 7 (12 marks). **Marks**

a) A softball player hits the ball from ground level with a speed of 20 m/s and an angle of elevation α . It flies toward a high wall 20m away on level ground. Taking the origin at the point where the ball is hit, the derived expressions for the horizontal and vertical components of x and y of displacement at the time t seconds, taking $g = 10\,\text{m/s}^2$, are $x = 20t\cos\alpha$ and $y = -5t^2 + 20t\sin\alpha$



(i) Hence find the equation of the path of the ball in flight in terms of x, y and α . 1

(ii) Show that the height h at which the ball hits the wall is given by $h = 20\tan\alpha - 5\left(1+\tan^2\alpha\right)$ 1

(iii) Using part (ii) above, show that the maximum value of h occurs when $\tan\alpha = 2$ and find this maximum height 2

Question 7 continued next page.

Question 7 continued

b) A particle of unit mass moves in a straight line. It is placed at the origin on the x-axis and is then released from rest. When at position x, its acceleration is given by:

$$-9x+\frac{5}{(2-x)^2}\ .$$

Prove that the particle ultimately moves between two points on the x-axis and find these points. 3

c) (i) For any angles α and β show that

$$\tan\alpha+\tan\beta=\tan(\alpha+\beta)[1-\tan\alpha\tan\beta]$$ 1

(ii) Prove, by mathematical induction, that

$$\tan\theta\tan2\theta+\tan2\theta\tan3\theta+...+\tan n\theta\tan(n+1)\theta=\tan(n+1)\theta\cot\theta-(n+1)$$

for all positive integers n 4

End of Question 7.

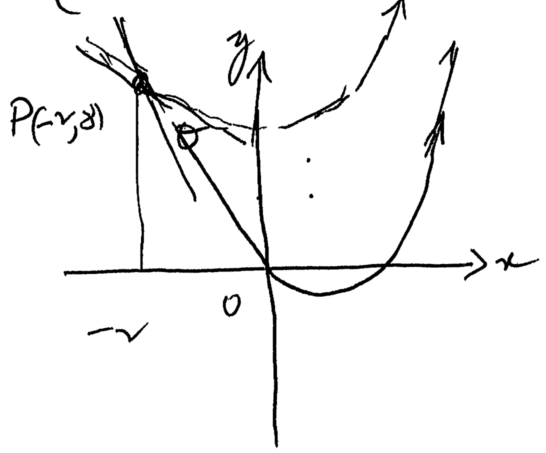
End of Examination.

QUESTION 1. (X1)

(a) Find the intersections let $x^2+4 = x^2-2x$.

$2x = -4$

$\underline{x = -2}$.



now $y = x^2+4$

$y' = 2x$

$\therefore m_1 = -4$

$y = x^2-2x$

$y' = 2x-2$

$m_2 = -6$.

$\tan\theta = \left|\dfrac{m_1-m_2}{1+m_1m_2}\right|$

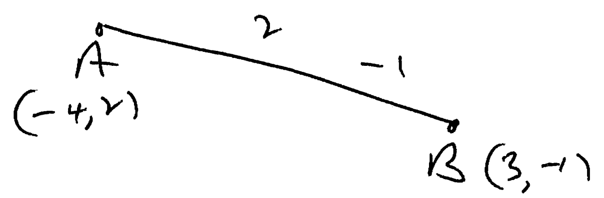
$= \left|\dfrac{-4--6}{1+-4\times-6}\right|$

$= \left|\dfrac{-4+6}{1+24}\right|$

$= \dfrac{2}{25}$

$\therefore \boxed{\theta = \tan^{-1}\frac{2}{25} = 4^0 34'}$

(b)



$P = \left(\dfrac{2\times3+-1\times-4}{2+-1}, \dfrac{2\times-1+-1\times2}{2+-1}\right)$

$= \boxed{(10, -4)}$

(c) $y = \ln(\sin^{-1}x)$

$y' = \dfrac{\frac{1}{\sqrt{1-x^2}}}{\sin^{-1}x} = \boxed{\dfrac{1}{\sin^{-1}x\sqrt{1-x^2}}}$

(d) $\dfrac{x-1}{x+3} \geqslant -2$

$\dfrac{x-1}{x+3} + 2 \geqslant 0$

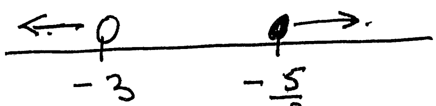
$\dfrac{x-1+2(x+3)}{x+3} \geqslant 0$

$\dfrac{x-1+2x+6}{x+3} \geqslant 0$

$\dfrac{3x+5}{x+3} \geqslant 0$

$\dfrac{(3x+5)}{(x+3)} \times (x+3)^2 \geqslant 0$

$(3x+5)(x+3) \geqslant 0$



$\therefore \boxed{x < -3, \quad x \geqslant -\frac{5}{3}}$

(e)

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

$= 1 - 2 \times \left(\frac{1}{3}\right)^2$

$= 1 - \frac{2}{9}$

$= \frac{7}{9}$

$\therefore \cos 2B = \frac{7}{9} = \cos A$

$\therefore \boxed{A = 2B}$

[NB doing this question on a calculator is not a proof]

(f) $u = t+1$

$du = dt$

$$\therefore \int_0^1 \frac{t}{\sqrt{1+t}}\,dt = \int_1^2 \frac{u-1}{\sqrt{u}}\,du$$

$$= \int_1^2 \left(u^{\frac{1}{2}} - u^{-\frac{1}{2}}\right) du$$

$$= \left[\frac{2}{3}u^{3/2} - 2u^{\frac{1}{2}}\right]_1^2 = \frac{2}{3} \cdot 2^{3/2} - 2 \cdot 2^{\frac{1}{2}} - \left(\frac{2}{3} - 2\right)$$

$$= \frac{4\sqrt{2}}{3} - 2\sqrt{2} - \frac{-4}{3}$$

$$= \frac{4}{3} - \frac{2\sqrt{2}}{3}$$

$$= \boxed{\frac{4 - 2\sqrt{2}}{3}}$$

Question 2

a) $P(x) = ax^3 + bx^2 - 8x + 3$

$P(1) = 0$

$\therefore 0 = a + b - 8 + 3$

$\boxed{a + b = 5} \quad \boxed{1}$

$P(-2) = 15$

$15 = -8a + 4b + 16 + 3$

$\boxed{8a - 4b = 4} \quad \boxed{2}$

1 $\times 4$

$4a + 4b = 20 \quad 3$

2 + 3

$12a = 24$

$\boxed{a = 2}$ 1 mark

sub into 1

$2 + b = 5$

$\boxed{b = 3}$ 1 mark

$\therefore P(x) = 2x^3 + 3x^2 - 8x + 3$

$$
\begin{array}{r}
2x^2 + 5x - 3 \\
x - 1 \overline{)\, 2x^3 + 3x^2 - 8x + 3} \\
2x^3 - 2x^2 \qquad\qquad \\
\hline
5x^2 - 8x + 3 \\
5x^2 - 5x \qquad \\
\hline
-3x + 3 \\
-3x + 3 \\
\hline
0
\end{array}
$$

$2x^2 + 5x - 3$ $\quad {}^{-6}$

$= \dfrac{(2x + 6)(2x - 1)}{2}$

$= \dfrac{\cancel{2}(x + 3)(2x - 1)}{\cancel{2}}$

$\therefore P(x) = (x - 1)(x + 3)(2x - 1)$

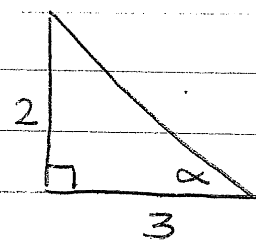
1 mark

b) i $3\sin\theta + 2\cos\theta$

$= R\sin(\theta + \alpha)$

$R = \sqrt{3^2 + 2^2}$

$= \sqrt{13}$ 1 mark



$\tan\alpha = \dfrac{2}{3}$

$\alpha = \tan^{-1} 2/3$

$= 33°41'$

1 mark

ii $\sqrt{13}\sin(\theta + 33°41') = \dfrac{5}{2}$

$\sin(\theta + 33°41') = \dfrac{5}{2\sqrt{13}}$

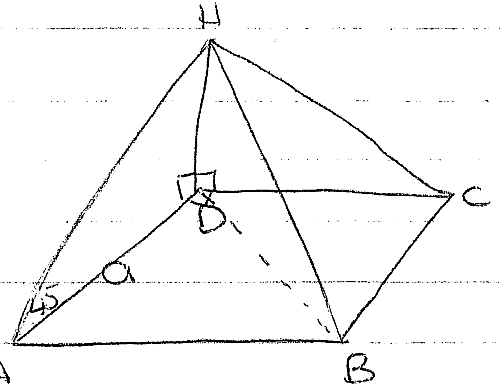
$\theta + 33°41' = \sin^{-1} \dfrac{5}{2\sqrt{13}}$

$\theta = \sin^{-1} \dfrac{5}{2\sqrt{3}} - 33°41'$

$\theta = 10°13', \; 102°25'$

1 mark each

c)



i) $\angle AHD = 45^\circ$

$\therefore \triangle AHD$ is isosceles

$\therefore HD = a$

In $\triangle$'s HCD + DBA

$HD = a = DA$

$\angle HDC = 90^\circ = \angle DAB$

(given & properties of a rectangle)

$DC = AB$ (opposite sides of a rectangle)

$\therefore \triangle HCD \equiv \triangle DBA$ (SAS)

$\therefore \angle DBA = 30^\circ$

1mark

In $\triangle DAB$

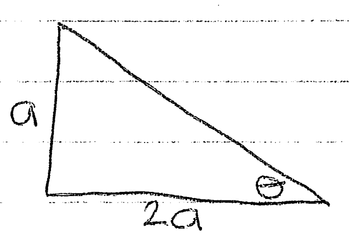
$$\sin 30 = \frac{a}{BD}$$

$$\tfrac{1}{2} = a/BD$$

$\therefore BD = 2a$

1mark

ii) $\triangle HDB$



$\tan\theta = a/2a$

$\tan\theta = \tfrac{1}{2}$

$\theta = 26^\circ 33' 54.18''$

$= 26^\circ 34'$ (nearest min)

1mark

d) $a_1 = a - \dfrac{f(a)}{f'(a)}$

$f(x) = 2x + \cos x$

$f'(x) = 2 - \sin x$

$a = -\pi/6$

$f(a) = \dfrac{-\pi}{3} + \dfrac{\sqrt{3}}{2}$

$f'(a) = 2 - -\tfrac{1}{2}$

$= 5/2$

1 mark

$$a_1 = -\pi/6 - \left[\frac{-2\pi + 3\sqrt{3}}{6}\right] \div \frac{5}{2}$$

$$= \frac{-\pi}{6} - \left[\frac{-4\pi + 6\sqrt{3}}{30}\right]$$

$$= -\frac{5\pi}{30} + \frac{4\pi - 6\sqrt{3}}{30}$$

$$= \frac{-\pi - 6\sqrt{3}}{30}$$ 1mark

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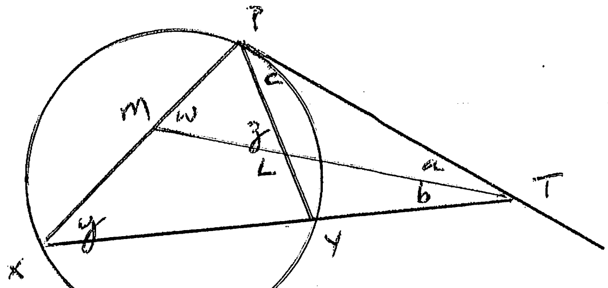
Question 3:



$a = b$ (TM bisects $\angle PTX$, given)

$c = y$ (alternate segment theorem)

$z = a + c$ (exterior $\angle$ of ΔPLT)

$\quad = b + y$

$w = b + y$ (exterior $\angle$ of Δ MTX)

$\therefore z = w$

$\therefore \Delta PLM$ is isosceles (base angles equal)

3

(b) (i) $f^{-1}(x) = \sin^{-1}(3x-1)$

Domain: $-1 \le 3x - 1 \le 1$

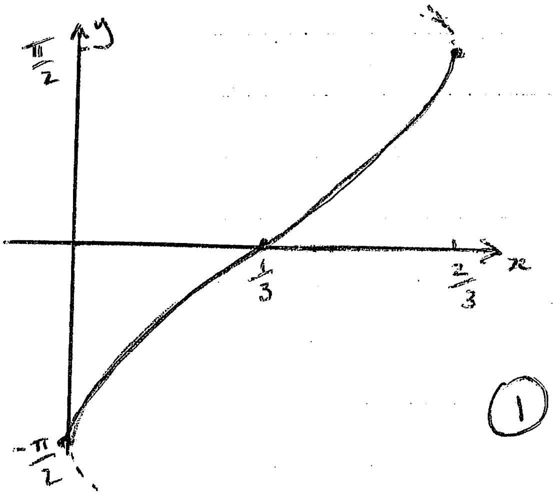
$0 \le 3x \le 2$

$0 \le x \le \frac{2}{3}$

2

Range: $-\frac{\pi}{2} \le y \le \frac{\pi}{2}$

(ii)



1

(iii) $x = \sin^{-1}(3y-1)$

$\sin x = 3y - 1$

$3y = \sin x + 1$

$y = \frac{1}{3}(\sin x + 1)$

$f(x) = \frac{1}{3}(\sin x + 1)$

Domain: $-\frac{\pi}{2} \le x \le \frac{\pi}{2}$

Range: $0 \le y \le \frac{2}{3}$

3

(c) (i) $\frac{dT}{dt} = \frac{d}{dt}(T_0 + Ae^{-kt})$

$= Ae^{-kt} \times -k$

$= (T - T_0) \times -k$

$= -k(T - T_0)$

1

(ii) When $t = 0$: $T = 85°$

$\therefore 85 = 25 + A$

$\therefore A = 60$

$\therefore T = 25 + 60e^{-kt}$

When $t = 1$: $80 = 25 + 60e^{-k}$

$\therefore 55 = 60e^{-k}$

$\therefore e^{-k} = \frac{55}{60}$

$k = -\ln\left(\frac{55}{60}\right)$

When $t = 5$: $T = 25 + 60e^{-5k}$

$= 63.8336\ldots$

$\approx 64°$

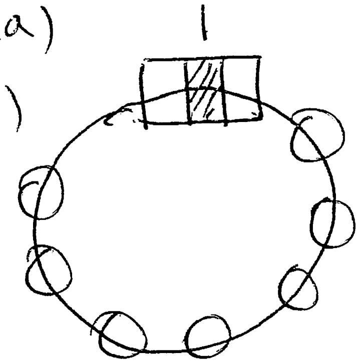
2

12

Solution to Q(4)

(a)

(i)



[1]

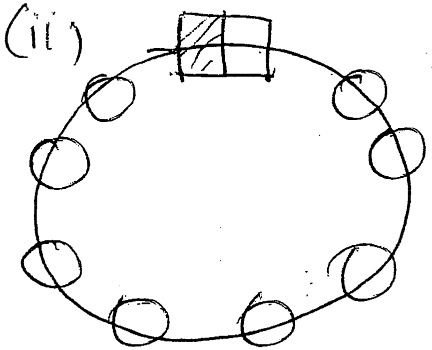
$7! \times 1 \times 2!$

the rest — particular girl — 2 boys

$= \boxed{2 \times 7!}$

$= \boxed{10080}$

(ii)



Sitting together

$= 8! \times 2!$

∴ Separate $= 9! - 8! \times 2!$

$= \boxed{282240}$ [1]

(b) $y = x^2/4a$

(i) $\dfrac{dy}{dx} = \dfrac{x}{2a}$ [2]

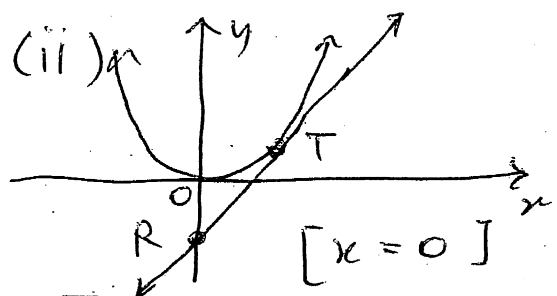
$\left.\dfrac{dy}{dx}\right|_{x=2at} = \dfrac{2at}{2a} = t$

∴ Equ. of tgt

$y - at^2 = t(x - 2at)$

$\boxed{y = tx - at^2}$

(ii)



$\boxed{R(0, -at^2)}$ [1]

If PQ passes through R then Coordinates of R Satisfy equation of PQ

i.e

$-at^2 + apq = 0$

$t^2 = pq$ [2]

i.e $\boxed{\dfrac{t}{p} = \dfrac{q}{t}}$

∴ p, t, q are terms of a geometric series

(c) $x = 2\cos 3t$, $\dot{x} = -6\sin 3t$

$\ddot{x} = -9(2\cos 3t) = -9x$

(i) ∴ $n^2 = 9$.

(ii) $T = \dfrac{2\pi}{n} = \boxed{\dfrac{2\pi}{3}}$ [1]

(iii) $\cos 3t = 1/2$, $3t = \dfrac{\pi}{3}, \dfrac{5\pi}{3}$

$\Rightarrow t = \dfrac{\pi}{9}, \dfrac{5\pi}{9}$

∴ $\dot{x} = -6\sin\dfrac{\pi}{3}, -6\sin\dfrac{5\pi}{3}$

$= \boxed{\pm 3\sqrt{3} \text{ cm/sec}}$

$\doteqdot \pm 5.196$ cm/se [2]

QUESTION 5.

(a) $\frac{\sin\theta}{\cos\theta} = 2\sin\theta\cos\theta$

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

$2\sin\theta(1-\sin^2\theta) - \sin\theta = 0.$

$2\sin^3\theta - \sin\theta = 0.$

$\sin\theta(2\sin^2\theta - 1) = 0.$

$\sin\theta = 0$ $\qquad$ $\sin\theta = \pm\frac{1}{\sqrt{2}}$

$\theta = \pi n \quad n \in \mathbb{Z}$ $\qquad$ $\theta = \pi n \pm \frac{\pi}{4} \quad n \in \mathbb{Z}$

(b) (i) $\alpha\beta + \beta\gamma + \alpha\gamma = \frac{1}{2}.$

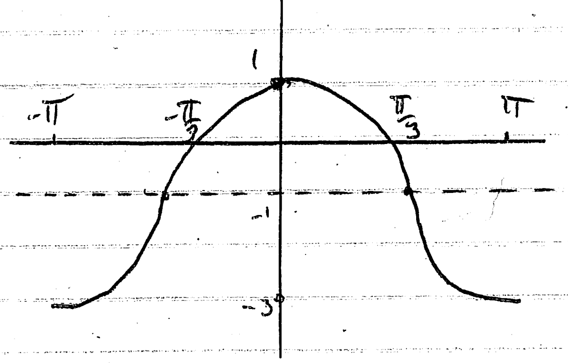
(ii) $\alpha\beta\gamma = \frac{1}{2}.$

$\frac{1}{\cos a} + \frac{1}{\cos b} + \frac{1}{\cos c} = \frac{\cos a\cos b + \cos a\cos c + \cos b\cos c}{\cos a\cos b\cos c.}$

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

$= 1$

(c) (i)



$2\cos x - 1 = 0$

$\cos x = \frac{1}{2}$

$x = \pm\frac{\pi}{3}.$

(iii)

$$V = \pi \int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} 4\cos^2 x - 4\cos x + 1 \, dx.$$

$$= \pi \int_{-\frac{\pi}{3}}^{\frac{\pi}{3}} 2\cos 2x + 2 - 4\cos x + 1 \, dx.$$

$$= \pi \left[\sin 2x - 4\sin x + 3x \right]_{-\frac{\pi}{3}}^{\frac{\pi}{3}}.$$

$$= 2\pi \left(\sin \tfrac{2\pi}{3} - 4\sin\tfrac{\pi}{3} + \pi \right).$$

$$= 2\pi^2 - 3\pi\sqrt{3}. \text{ units}^3.$$

Question 6

a) i) $\dfrac{d(\ln\cos y)}{dy} = \dfrac{-\sin y}{\cos y}$

$= \underline{\underline{-\tan y}}$

ii) $A = \int_0^{\frac{\pi}{4}} x \, dy$

$= \int_0^{\frac{\pi}{4}} \tan y \, dy$

$= -\int_0^{\frac{\pi}{4}} -\tan y \, dy$

$= -\left[\ln(\cos y)\right]_0^{\frac{\pi}{4}}$ using (i)

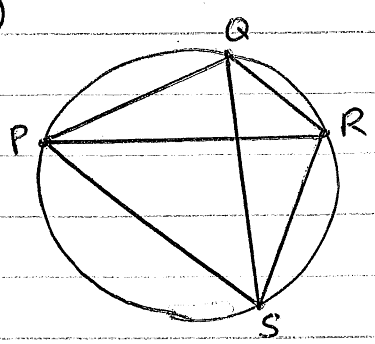
$= -\left(\ln\left(\cos\frac{\pi}{4}\right) - \ln(\cos 0)\right)$

$= -\ln\left(\frac{1}{\sqrt{2}}\right) + \cancel{\ln 1}$

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

$= \frac{1}{2}\ln 2$ units^2

b)



In $\triangle PQR$

$\dfrac{\sin P\hat{Q}R}{PR} = \dfrac{\sin Q\hat{R}P}{PQ}$

In $\triangle QPS$

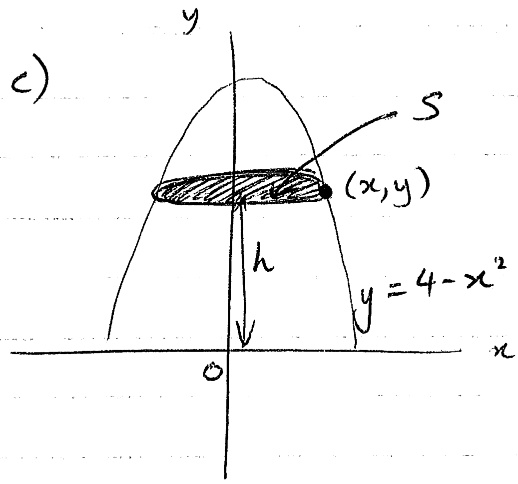
$\dfrac{\sin Q\hat{P}S}{QS} = \dfrac{\sin P\hat{S}Q}{PQ}$

$Q\hat{R}P = P\hat{S}Q$ (angles in same segment (arc PQ))

$\therefore \dfrac{\sin P\hat{Q}R}{PR} = \dfrac{\sin Q\hat{P}S}{QS}$

$\dfrac{\sin P\hat{Q}R}{\sin Q\hat{P}S} = \dfrac{PR}{QS}$

c)



i) $S = \pi r^2$

$S = \pi x^2$

when $y = h$

$h = 4 - x^2$

$x^2 = 4 - h$

$\therefore \ S = \pi(4 - h)$

ii) $S = 4\pi - \pi h$

$\frac{dS}{dh} = -\pi$

$\frac{dS}{dt} = \frac{dS}{dh} \times \frac{dh}{dt}$

$= -\pi \times \frac{10}{\pi(4-h)}$

$= -\frac{10}{4-h}$

when $h = 2$

$\frac{dS}{dt} = -\frac{10}{(4-2)}$

$= \underline{\underline{-5}}$ cm²/s

QUESTION 7

(a) $x = 20t\cos\alpha$

$y = -5t^2 + 20t\sin\alpha$

(i)

$\Rightarrow y = -5\left(\frac{x}{20\cos\alpha}\right)^2 + 20\left(\frac{x}{20\cos\alpha}\right)\sin\alpha$

$y = -\frac{1}{80}x^2\sec^2\alpha + x\tan\alpha$

ie $y = -\frac{1}{80}(\tan^2\alpha+1)x^2 + (\tan\alpha)x$

(ii) When $x=20$, $y=h$

$\Rightarrow h = -\frac{1}{80}(\tan^2\alpha+1)400 + 20\tan\alpha$

ie $h = -5\tan^2\alpha + 20\tan\alpha - 5$

$\boxed{h = 20\tan\alpha - 5(1+\tan^2\alpha)}$

(iii)

$h = -5\tan^2\alpha + 20\tan\alpha - 5$

Max. value of h occurs

when $\tan\alpha = \frac{-20}{2(-5)} = 2$

ie $\boxed{\tan\alpha = 2}$

Max height is

$-5(2)^2 + 20(2) - 5 = \boxed{15 \text{ metres}}$

(b) $\frac{d}{dx}\left(\frac{1}{2}v^2\right) = -9x + 5(x-2)^{-2}$

$\frac{1}{2}v^2 = \frac{-9x^2}{2} + \frac{5}{2-x} + c$

$\left.\begin{array}{l}x=0\\v=0\end{array}\right\} \Rightarrow c = -\frac{5}{2}$

$\therefore v^2 = -9x^2 + \frac{5}{2-x} - 5$

(b)(ctd) $v^2 = -9x^2 + \frac{10}{2-x} - 5$

For motion to exist then

$v^2 \geq 0$

ie $-9x^2 + \frac{10}{2-x} - 5 \geq 0$

$-9x^2(2-x)^2 + 10(2-x) - 5(2-x)^2 \geq 0$

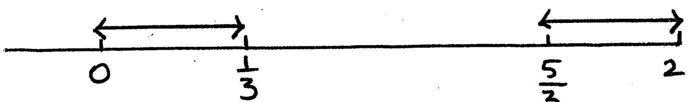
$(2-x)\left[-9x^2(2-x) + 10 - 5(2-x)\right] \geq 0$

ie $(2-x)(-18x^2 + 9x^3 + 5x) \geq 0$

ie $(2-x).x(9x^2 - 18x + 5) \geq 0$

$x(2-x)(3x-5)(3x-1) \geq 0$

SOLUTION



$0 \leq x \leq \frac{1}{3}$ $\quad$ $\frac{5}{3} \leq x \leq 2$

However since particle starts at zero and changes direction at $x = \frac{1}{3}$ it can never be outside the interval $0 \leq x \leq \frac{1}{3}$.

Note For $\frac{1}{3} < x < \frac{5}{3}$ $v^2 < 0$

$\therefore$ impossible to move in this interval and therefore cannot move in $\frac{5}{3} \leq x \leq 2$.

Ultimately moves in interval

$0 \leq x \leq \frac{1}{3}$

⑦ (c) (i)

$$\text{RHS} = \tan(\alpha+\beta)\left[1-\tan\alpha\tan\beta\right]$$
$$= \frac{\tan\alpha+\tan\beta}{1-\tan\alpha\tan\beta}\left[1-\tan\alpha\tan\beta\right]$$
$$= \tan\alpha+\tan\beta$$
$$= \text{LHS}$$

(ii) When $n=1$ $\quad \tan\theta\,.\tan2\theta = \tan2\theta\cot\theta - 2$

$$\text{RHS} = \frac{2\tan\theta}{1-\tan^2\theta}\cdot\frac{1}{\tan\theta} - 2 = \frac{2\tan^2\theta}{1-\tan^2\theta} = \tan\theta\,.\frac{2\tan\theta}{1-\tan^2\theta}$$
$$= \tan\theta\,.\tan2\theta = \text{LHS}$$

Assume $\tan\theta\tan2\theta + \dots + \tan k\theta\tan(k+1)\theta = \tan(k+1)\theta\cot\theta - (k+1)$

RTP $\tan\theta\tan2\theta + \dots + \tan k\theta + \tan(k+1)\theta + \tan(k+1)\theta\tan(k+2)\theta = \tan(k+2)\theta\cot\theta - (k+2)$

Now $\text{LHS} = \tan(k+1)\theta\,.\cot\theta - (k+1) + \tan(k+1)\theta\tan(k+2)\theta$

$$= \cot\theta\left[\tan(k+1)\theta + \tan(k+1)\theta\,.\tan(k+2)\theta\,.\tan\theta\right] - (k+1)$$
$$= \cot\theta\left[\tan(k+1)\theta + \tan(k+2)\theta\left(1 - \frac{\tan(k+1)\theta+\tan\theta}{\tan(k+2)\theta}\right]\right] - (k+1)$$

using (i)

$$= \cot\theta\left[\tan(k+1)\theta + \tan(k+2)\theta - \tan(k+1)\theta - \tan\theta\right] - (k+1)$$
$$= \cot\theta\left[\tan(k+2)\theta - \tan\theta\right] - (k+1)$$
$$= \cot\theta\left[\tan(k+2)\theta\right] - 1 - (k+1)$$
$$= \cot\theta\left[\tan(k+2)\theta\right] - (k+2) \quad = \text{RHS}$$