# J.R.A.H.S. TRIAL HSC EXAMINATION 3/4 UNIT MATHEMATICS 1995

## QUESTION 1 (Start a new page)

(a) Express 0.373737....... as a proper fraction in simplest form.

(b) Find the size of the acute angle between the lines $2x + y = 5$ and $3x - y = 1$.

(c) Find all solutions to : $\frac{1}{x-2} \leq 4$ .

(d) Differentiate with respect to x: $y = \tan^{-1} 2x$.

(e) Solve $2\cos^2 x + 3\sin x - 3 = 0$, for $0 \leq x \leq 2\pi$.

## QUESTION 2 ( Start a new page )

(a) Prove the identity: $\frac{\sin 2\theta}{1 + \cos 2\theta} = \tan\theta$ .

(b) Given that $\frac{dy}{dx} = \frac{1}{1+x^2}$, and x=1 when y=0, find y when $x = \sqrt{3}$ .

(c) Evaluate : $\int_0^{\sqrt{3}} \frac{dx}{\sqrt{3-x^2}}$

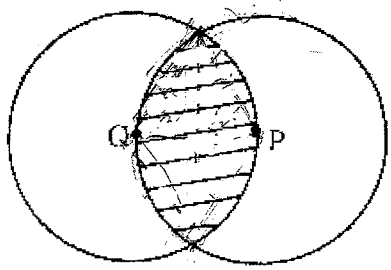
(d) Prove by mathematical induction that $3^{4n} - 1$ is divisible by 80 for all positive integers n.

## QUESTION 3 ( Start a new page)

(a) Let the equation of motion of an object moving x metres along a straight line after t seconds be: $x(t) = 4\sin 3t - 5\cos 3t$ $(t \geq 0)$. Show that its motion is Simple Harmonic, and find its period of motion.

(b) Evaluate : $\int_0^{\frac{\pi}{8}} \cos^2 2x\,dx$

(c) In the diagram shown, the two circles are of radius 1 metre and pass through centres O and P. Find the area of their intersection (to two decimal places).



JKAHS 30

QUESTION 4 ( Start a new page )

(a) If 5% of monkeys are colourblind, what is the probability that a random sample of 20 monkeys should contain at least two colourblind monkeys? (Answer to three decimal places.)

(b) A person invests \$1000 at the beginning of each year in a superannuation fund. If interest is paid at 9% per annum, find :

(i) the value of the investment at the end of 30 years.
(ii) how many years would elapse for the investment to be worth \$50,000.

(c) Neatly sketch $y = 3\cos^{-1}\pi x$, and state its domain and range.

QUESTION 5 (Start a new page)

(a) The acceleration of a particle is given by $\frac{d^2x}{dt^2} = 16(1 + x)$, where $x$ cm. is the displacement from the origin. When $t = 0$, $x = 0$ and $v = 4$cm./ sec.

(i) Derive an expression for its velocity in terms of its displacement.
(ii) Deduce that its displacement function is $x(t) = e^{4t} - 1$.

(b) Evaluate $\cot 2\theta$ if $\cot^2\theta - \cot\theta = 1$

(c) ABCD and AEFG are two squares of different areas, and $GD \perp BE$ . M is the mid point of DE.

(i) Give a reason why DE is the diameter of the circle with points A,D and E on its circumference.
(ii) Prove that BDEG is a cyclic quadrilateral.
(iii) Prove that $AM \perp BG$ .

Copy the diagram below onto your answer sheet.

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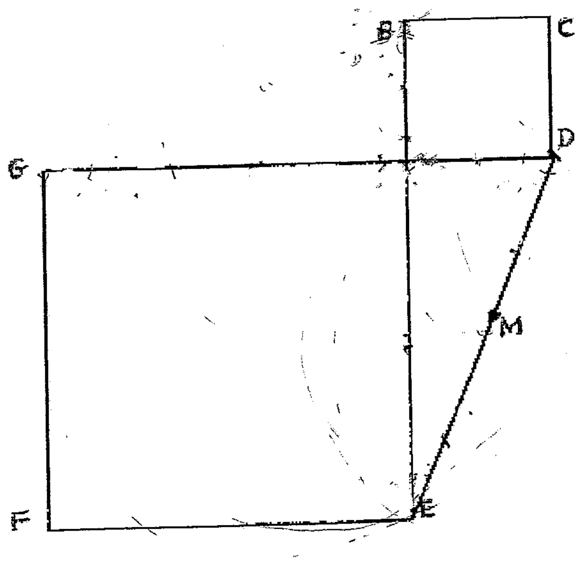
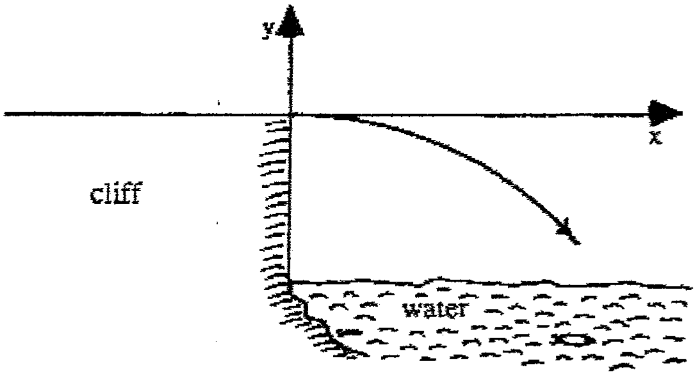


## QUESTION 6 ( Start a new page )

(a) An object is projected horizontally from the top edge of a vertical cliff 40 metres above sea level with a velocity of 40m/s. ( Take $g = 10$ m/s$^2$ )




(i) Using the top edge of the cliff as origin, prove that the parametric equations of the path of the object are:

$$x = 40t \qquad y = -5t^2$$

(ii) Calculate when and where the object hits the water.
(iii) Find the velocity ( magnitude and direction ) of the object the instant it hits the water.

(b) The inside of a vessel used for water has the shape of a solid of revolution obtained by the rotation of the parabola $9y = 8x^2$ about the y - axis. The depth of the vessel is 8 cm.

(i) Prove that a volume of water h cm. from its bottom is $\frac{9}{16}\pi h^2$.

(ii) If water is poured into the vessel at a rate of 20 cm$^3$/sec., find the rate at which the level of water is rising when the vessel is half full.

## QUESTION 7 ( Start a new page )

(a) Two parametric points $P(2p,p^2)$ and $Q(2q,q^2)$ lie on the parabola $x^2 = 4y$, and the line through PQ is parallel to the line $y = mx$.

(i) Show that $p + q = 2m$.
(ii) Derive the equation of the normal to the parabola at the point P.
(iii) Find the co-ordinates of N, the point of intersection of the normals from P and Q.
(iv) Determine the locus of N as the line PQ moves parallel to the line $y = mx$. State any restrictions on the locus of N.

(b) $A_n$ and $B_n$ are two series given by :

$$A_n = 1^2 + 5^2 + 9^2 + 13^2 + \ldots\ldots + (4n-3)^2$$
$$B_n = 3^2 + 7^2 + 11^2 + 15^2 + \ldots\ldots \qquad \text{for } n = 1,2,3,\ldots$$

(i) Find the nth term of $B_n$.
(ii) If $S_{2n} = A_n - B_n$, prove that $S_{2n} = -8n^3$.
(iii) Hence, or otherwise, evaluate :
$101^2 - 103^2 + 105^2 - 107^2 + \ldots\ldots + 1993^2 - 1995^2$.

**END OF PAPER**

SOLUTIONS

1 (a) $\frac{37}{49}$

(b) $\pi/4$

(c) $x<2$, $x \geq 9/4$

(d) $\frac{2}{1+4x^2}$

(e) $\pi/6$, $5\pi/6$, $\pi/2$

2 (a) —

(b) $\pi/12$

(c) $\pi/2$

(d) [illegible]

3 (a) $T = 2\pi/3$

(b) $\pi/16 + 1/8$

(c) 2.3 (1D)

4 (a) 0.264 (3D)

(b) (i) \$145 575

(ii) 19 (nearest yr)

c) D: $-\frac{1}{\sqrt{2}} \leq x \leq \frac{1}{\sqrt{2}}$

R: $0 \leq y \leq 3\pi$

5 (a) (i) $v^2 = 4(1+x)$

(ii) —

(b) $\frac{1}{2}$

(c) —

6 (a) (i) —

(ii) $80\sqrt{2}$, $t = 2\sqrt{2}$ sec

(iii) 35° with speed $20\sqrt{5}$ m/s

(b) " $\frac{20\sqrt{2}}{45}$ m/s

7 (a) (i) —

(ii) $x + py = p^3 + 2p$

(iii) $N\left[-pq(p+q), p^2+q^2+pq+2\right]$

(iv) $y = \frac{x}{2m} + 4m^2 + 2$

Restriction $y > 3m^2 + 2$

$x > -2m^3$

(b) (i) $T_n = (4n-1)^2$

(ii) —

" —

TRAMS – HSC – 3/4 unit (1998) 7

1. a) $0.3737\ldots = \cancel{0.3 + 0.0}$

$= 0.303030\ldots + 0.070707\ldots$

$= [.3 + .003 + .00003\ldots] + [.07 + .0007\ldots]$

$a = 0.3$ $\qquad$ $a = 0.07$
$r = .001$ $\qquad$ $r = .\cancel{000}01$

$= \frac{0.3}{1-0.001} + \frac{0.07}{1-.01}$

$= \frac{10}{33} + \frac{7}{99}$

$= \frac{37}{99}$.

b) $2x + y = 5$ $\qquad$ $3x - y = 1$

$m = -2$ $\qquad$ $m = 3$

$\tan\theta = \left| \frac{3 + 2}{1 - 3(2)} \right|$

$\tan\theta = \frac{5}{-5} = 1$

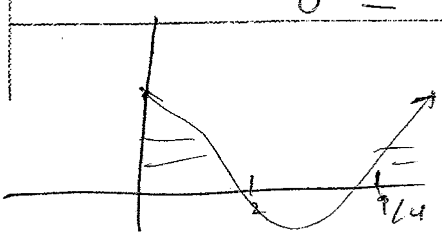
$\cancel{\theta = 8.1°}$ $\qquad$ $\theta = \pi/4$.

c) $\cancel{\frac{1}{x-2}} \leq 4(x-2)^2$ $\qquad (x-2)^2$

$0 \leq 4(x-2)^2 - (x-2)$

$0 \leq (x-2)[4(x-2)-1]$

$0 \leq (x-2)[4x-9]$




$\boxed{x < 2 \text{ or } x \geq 9/4}$

d) $y = \tan^{-1} 2x.$

$$y' = \frac{2}{1+4x^2}.$$

e) $2\cos^2 x + 3\sin x - 3 = 0 \qquad 0 \le x \le 2\pi$

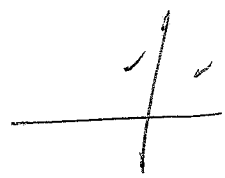
$= 2(1-\sin^2 x) + 3\sin x - 3 = 0.$

$2 - 2\sin^2 x + 3\sin x - 3 = 0.$

$0 = 2\sin^2 x - 3\sin x + 1$

$2\sin x \quad -1$

$\sin x \quad -1$



$0 = (2\sin x - 1)(\sin x - 1)$

$\sin x = 1 \qquad | \qquad \sin x = \frac{1}{2}$

$x = \frac{\pi}{2}, \qquad | \qquad x = \frac{\pi}{6}, \quad \frac{5\pi}{6}$

$x = \frac{\pi}{2}, \quad \frac{\pi}{6}, \quad \frac{5\pi}{6}.$

2) $$\frac{\sin 2\theta}{1+\cos 2\theta} = \tan\theta$$

LHS: $$\frac{2\sin\theta\cancel{\cos\theta}}{\cancel{1}+2\cos^2\theta\cancel{-1}} = \tan\theta.$$

6) $(1, 0)$ $$y = \int \frac{1}{1+x^2}\,dx$$

$= (\tan^{-1}x) + c$

$0 = \tan^{-1} 1 + c$

$c = -\pi/4$

$y = \tan^{-1}x - \pi/4.$

$y = \tan^{-1}\sqrt{3} - \pi/4$

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

$= \frac{4\pi - 3\pi}{12} = \frac{\pi}{12}$

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2. c) $\displaystyle\int_0^{\sqrt{3}} \frac{dx}{\sqrt{3-x^2}}$ $\quad a = \sqrt{3}.$

$= \left(\sin^{-1}\frac{x}{\sqrt{3}}\right)_0^{\sqrt{3}}$

$= \sin^{-1} 1 - \sin^{-1} 0$

$= \frac{\pi}{2}.$

d) $P(n): \; 3^{4n} - 1 = 80\,m$ (m is an integer)

Consider $P(1)$:

$3^4 - 1 = 80 = 80(1)$

$\therefore P(1)$ is true

Assume $P(k)$ is true;

$3^{4k} - 1 = 80\,\cancel{k}.M$ — (A) ~~(N = 1~~

Consider $P(k+1)$:

$3^{4k+4} - 1 = 80N$ (N = integer)

By (A); $3^4(3^{4k}-1) + 3^4 - 1$

$= 3^4(80m) + 3^4 - 1$

$= 6480m + 80$

$= 80(81m+1)$

$= 80N$ (81 m+1 is an integer)

3. a) $x(t) = 4\sin 3t - 5\cos 3t \qquad (t \geq 0)$

$v = 12\cos 3t + 15 \cancel{\cos}\,\sin 3t.$

$a = -36\sin 3t + 45 \cancel{\sin} \cos 3t$

$= -9(4\sin 3t + 5\cos 3t)$

$a = -9x \qquad (\text{where } n = 3)$

$T = \frac{2\pi}{3}\text{ s}$

b) $\int_0^{\pi/8} \cos^2 2x \, dx$

$= \frac{1}{2}\int_0^{\pi/8} 1 + \cos 4x \, dx$

$= \frac{1}{2}\left[x + \frac{1}{4}\sin 4x\right]_0^{\pi/8}$

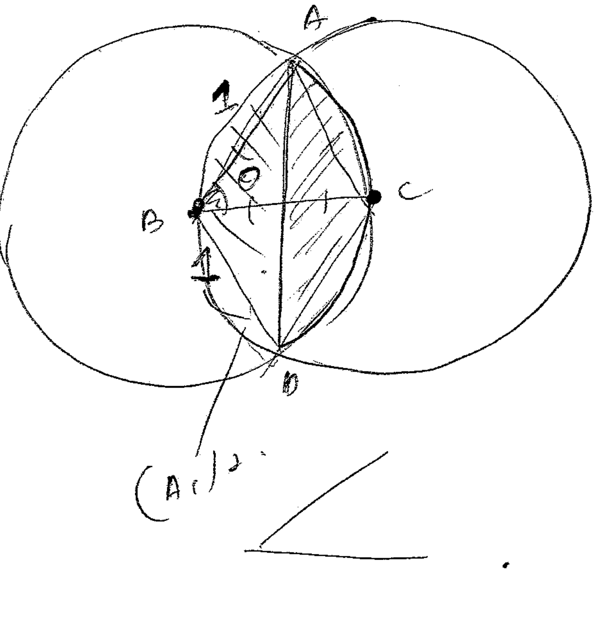
$= \frac{1}{2}\left(\frac{\pi}{8} + \frac{1}{4}\sin\frac{\pi}{2}\right) - 0$

$= \frac{\pi}{16} + \frac{\sin \pi/2}{8}$

$= \frac{\pi}{16} + \frac{1}{8}$ ✓

$= \frac{\pi + 2}{16}$

c)




$A = 2\left(\frac{1}{2}r^2(\theta - \sin\theta)\right)$

$= \cancel{2}\left(\frac{1}{\cancel{2}}(1)^2(\theta - \sin\theta)\right)$

$= (\theta - \sin\theta)$

In $\Delta ABC$; $AB = AC = BC = 1$

$\therefore \Delta ABC$ is equilateral

$\therefore \angle ABC = 60°$

$\angle ABD = 120° = \frac{2\pi}{3}$

$A = \frac{2\pi}{3} - \sin 120$

$= 1.23$ ✓

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3

4. a) $p = 0.05$

$q = 0.95$

$(p+q)^{20}$

$1 - (P(0) + P(1))$

$= 1 - [\,{}^{20}C_0\, p^0 q^{20} + {}^{20}C_1\, p q^{19}]$

$= 1 - [\,{}^{20}C_0\,(0.95)^{20} + {}^{20}C_1\,(0.05)(0.95)^{19}]$

$= 0.264.$ ✓

b) \$1000 $(1.09)$

i) $A_n = 1000\,(1.09)$

$A_2 = (1000(1.09) + 1000)(1.09)$

$= 1000\,(1.09 + 1.09^2)$

$A_{30} = 1000\,(1.09 + 1.09^2 \ldots + 1.09^{30})$

$a = 1.09$
$r = 1.09 \quad n = 30$

$= 1000 \left[ \dfrac{(1.09)\,[(1.09)^{30} - 1]}{.09} \right]$

$= \$148575.22.$ ✓

ii) $50000 = 1000 \dfrac{(1.09)\,[(1.09)^n - 1]}{.09}$

$5.1284 = 1.09^n$

$\log_{1.09} 5.1284 = n$

$n = 18.9$ yrs.

✓ $\approx 19$ yrs.

5) $a = 16(1+x)$

$t=0;\ x=0;\ v=4$

i) $16(1+x) = \frac{d}{dx}\left(\frac{1}{2}v^2\right)$

$\frac{1}{2}v^2 = 16\int 1+x\ dx$

$\frac{1}{2}v^2 = 16\left(x+\frac{x^2}{2}\right)+c.$

$\frac{v^2}{2} = 16x+8x^2+c$

$x=0;$ $v=4$ $\quad 8 = c$

$\frac{v^2}{2} = 16x+8x^2+8$

$v^2 = 32x+16x^2+16.$

ii) $\frac{dx}{dt} = \sqrt{32x+16x^2+16.}$

$\cancel{\frac{dt}{dx} = (32x+16x^2+16)^{-\frac{1}{2}}}$

$\cancel{t = \int (32x+16x^2+16)^{-1/2}}\ dx.$

$= \sqrt{16(x^2+2x+1.)}$

$= \sqrt{16(x+1)^2}$

$\frac{dx}{dt} = \cancel{16}4(x+1)$ ✓

$\frac{dt}{dx} = \frac{1}{4(x+1)}$

$t = \frac{1}{4}\int \frac{1}{x+1}\ dx.$

$t = \frac{1}{4}(\log_e(x+1)+c$

$x=0;\ t=0$

$0 = \frac{1}{4}\ln 1+c.\ ;\ c=0$

$t = \frac{1}{4}\log_e(x+1)$

$4t = \log_e(x+1)$

$e^{4t} = x+1$

$x = e^{4t}-1$

8. b) $\cot 2\theta$ $\qquad\qquad$ $\cot^2\theta - \cot\theta = 1.$

$= \cot(\theta + \theta)$

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

$= \dfrac{1 - \tan^2\theta}{2\tan\theta}$

$= \dfrac{1}{2\tan\theta} - \dfrac{\tan^2\theta}{2\tan\theta}$

$= \frac{1}{2}\cot\theta - \tan\theta$

$\cot 2\theta$

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

$= \dfrac{1 - \tan^2\theta}{2\tan\theta} = \dfrac{1}{2\tan\theta} - \dfrac{\tan\theta}{2}$

$= \frac{1}{2}\cot\theta - \dfrac{1}{2\cot\theta}$

$= \dfrac{\cot^2\theta - 1}{2\cot\theta}$

$= \dfrac{\cancel{\cot\theta}}{2\cancel{\cot\theta}}$

$= \frac{1}{2}$

5. c) $\angle DAE = 90°$ ($GD \perp BE$)

$\therefore$ ED is diameter ($\angle$ in semicircle $= 90°$)

ii) $\triangle BAG \equiv \triangle DAE$ (SAS)

$\therefore \angle GBA = \angle EDA$ (corresp. $\angle$'s in $\equiv \triangle$'s)

$\therefore$ BDEG is a cyclic quad ($\angle$s in same segment are equal)

iii) (check).

6. a) $\ddot{x} = 0$ | $\ddot{y} = -10$

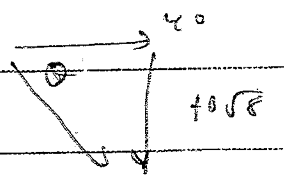
$\dot{x} = 40$ | $\dot{y} = -10t$

$x = 40t$ | $y = -5t^2$

ii) $-40 = -5t^2$

$t = \sqrt{8}$ s. $\quad x = 40\sqrt{8}$

iii) At $t = \sqrt{8}$; $\dot{y} = -10\sqrt{8}$ ; $\dot{x} = 40$



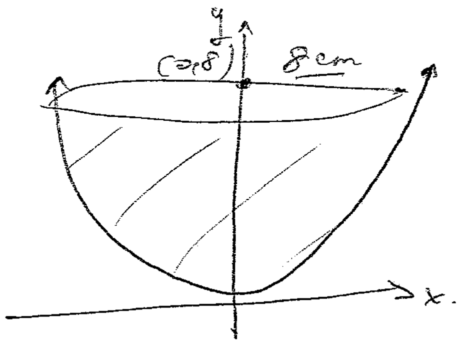

$\tan\theta = \frac{10\sqrt{8}}{40}$

$\theta = 35.3°$ ✓

$v = \sqrt{40^2 + (10\sqrt{8})^2} = 48.9$ ✓✓ m.

iii)

b) $\overset{9}{\cancel{8}}y = \cancel{8}x^2$




i) $v = \pi \int_0^h x^2 \, dy.$

$= \pi \int_0^h \frac{9y}{8} \, dy.$

$= \frac{9\pi}{8} \left( \frac{y^2}{2} \right)_0^h$

$v = \frac{9\pi}{8} \left[ \frac{h^2}{2} \right]$

$$\boxed{V = \frac{9\pi h^2}{16}}$$

ii) $\frac{dV}{dt} = 20$

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

$v = \frac{\cancel{2}9\pi}{\cancel{16}} h^2$

$\frac{dV}{dh} = \frac{9\pi}{8} \cancel{h}4 = \frac{9\pi \cancel{8}4}{\cancel{8}\cancel{8}2} = 9\pi \quad (h = \cancel{8}4) \quad = \frac{9\pi}{2}$

$\frac{dh}{dV} = \frac{2}{9\pi}.$

$\frac{dh}{dt} = \cancel{\frac{20 \times 1}{9\pi}} \quad 20 \times \frac{2}{9\pi} = \frac{40}{9\pi}$ cm/s.

?

b) $A_n = 1^2 + 5^2 + 9^2 + 13^2 \dots + (4n-3)^2$

$B_n = 3^2 + 7^2 + 11^2 + 15^2 + \dots$

ii) $B_n = (4n-1)^2$ ✓

iii) $S_{2n} = A_n - B_n$

$A_n - B_n$:

$(1^2 + 5^2 + 9^2 \dots + (4n-3)^2) - (3^2 + 7^2 + 11^2 \dots + (4n-1)^2)$

$= 1^2 - 3^2 + 5^2 - 7^2 + 9^2 - 11^2 \dots + (4n-3)^2 - (4n-1)^2 \dots$

$= 1 - 9 + 25 - 49 + 81 - 121 \dots + (4n-3)^2 - (4n-1)^2$

$16n^2 - 24n + 9 - (16n^2 - 8n + 1)$

$n = ??$

$= [-16n + 8]$

$n = 1$

$\Rightarrow [-16 + 8] + [-16(2) + 8] + [-16(3) + 8] \dots + [-16n + 8]$

$-8 \qquad -24 \qquad -40$

$= -8 - 24 - 40 - 46 \dots + [-16n + 8]$

$\therefore A_n - B_n$ is AP with $a = -8$, $d = -16$, $n = n$.

$= \frac{n}{2}(2(-8) + (n-1)(-16))$

$= \frac{n}{2}(-16 - 16(n-1))$

$= \frac{n}{2}(\cancel{-16} - 16n + \cancel{16})$

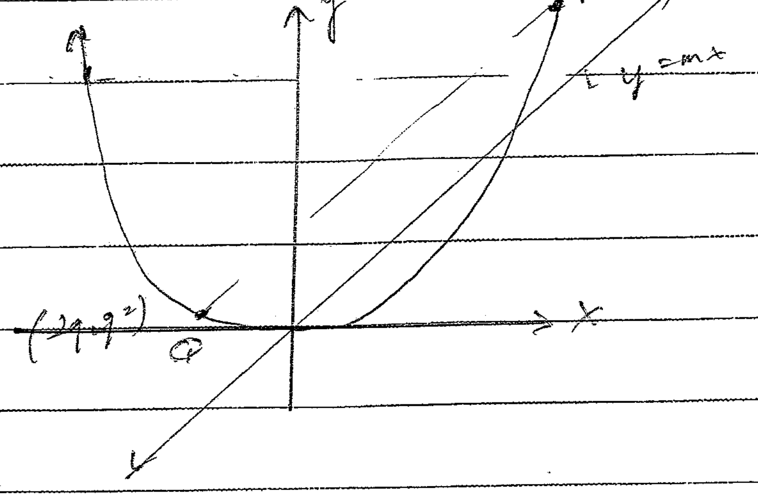
$= \underline{\underline{-8n^2}}$ ✓✓✓✓

$(4n-3) = 1001$

$4n = 104$

$n = 26$

7. a) $P(2p, p^2)$ $Q(2q, q^2)$ $P(2p, p^2)$




i) $m_{PQ} = m$

$\frac{p^2 - q^2}{2p - 2q} = m$

$\frac{(p-\cancel{q})(p+q)}{2(p-\cancel{q})} = m$

$p + q = 2m.$

ii) ~~$m = y' =$~~ $y = x^2/4$ ; $y' = 2x/4 = x/2$.

$= 2p/2 = p$

$m_N = -\frac{1}{p}$ $(2p, p^2)$

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

$yp - p^3 = -(x - 2p)$

$\boxed{x + py = 2p + p^3}$

iii) Q; $x + qy = 2q + q^3.$

$N[-pq(p+q],\ p^2 + q^2 + pq + 2)$

$x = -pq(p+q) = \boxed{-2mpq. = x}$

$y = p^2 + q^2 + pq + 2$ $pq = \frac{x}{-2m}$ — ②

$y - 2 = (p+q)^2 - pq$

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

$\boxed{y - 2 = 4m^2 - pq}$ ① ; $y - 2 = 4m^2 + \frac{x}{2m}$

b) $A_n = 1^2 + 5^2 + 9^2 + 13^2 \ldots + (4n-3)^2$

$B_n = 3^2 + 7^2 + 11^2 + 15^2 + \ldots$

1 2.

ii) $B_n = (4n-1)^2$ ✓ $\cancel{a} = 3^2$

iii) $S_{2n} = A_n - B_n$

$A_n - B_n$:

$(1^2 + 5^2 + 9^2 \ldots + (4n-3)^2) - (3^2 + 7^2 + 11^2 \ldots + (4n-1)^2)$

$= 1^2 - 3^2 + 5^2 - 7^2 + 9^2 - 11^2 \ldots + (4n-3)^2 - (4n-1)^2$

$= 1 - 9 + 25 - 49 + 81 - 121 \ldots + (4n-3)^2 - (4n-1)^2$

$\cancel{16n^2} - 24n + 9 - (\cancel{16n^2} - 8n + 1)$ $n = ??$

$= [-16n + 8]$

$n = 1$

$\Rightarrow [-16 + 8] + [-16(2) + 8] + [-16(3) + 8] \ldots + [-16n + 8]$

$-8 \quad -24 \quad -40$

$= -8 - 24 - 40 - 46 \ldots + [-16n + 8]$

$\therefore A_n - B_n$ is AP with $a = -8$, $d = -16$, $n = n$.

$= \frac{n}{2}(2(-8) + (n-1)(-16))$

$= \frac{n}{2}(-16 - 16(n-1))$

$= \frac{n}{2}(\cancel{-16} - 16n + \cancel{16})$

$= \underline{\underline{-8n^2}}$ ✓✓✓✓

$(4n-3) = 1001$

$4n = 104$

$n = 26$

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Close form

iii) $101^2 + 103^2 + 105^2 - 107^2 \ldots + 1993^2 - 1995^2$

$= -8 \quad \cancel{\quad} = -8n^2$

$101 + 105 + 109$

$a = 101 \quad d = 4. \quad ; \quad (101 + (n-1)4)^2$

$(4n-3)^2 - (4n-1)^2$

$1^2 + \quad\quad -8(26)^2$

HSC 2002 - English (Advanced) Paper 2
Exemplar Sample 1

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~~In $\triangle PQR$~~;

$\frac{PR}{QS} = \frac{\sin \angle PQR}{\sin \angle QPS}$ $\quad \frac{PR}{\sin \angle PQR} = \frac{QR}{\sin \angle QPR}$.

$QR = \frac{PR \sin(\angle QPR)}{\sin(\angle PQR)}$

~~In $\triangle QRS$~~; But $\angle QPR = \angle QSR$.

QR