Individual Events

I1	a	1	I2	R	$*\dfrac{9}{25}$ see the remark	I3	S	10	I4	k	1
	b	$\dfrac{1}{2}$		S	1		R	30		r	2
	C	10		T	1		T	6		s	$\dfrac{1}{\sqrt{2}}\,(=\dfrac{\sqrt{2}}{2})$
	D	–2		W	$\sqrt{5}$		P	$\sqrt{7}+2$		w	9

Group Events

G1	k	1	G2	w	45	G3	r	2006	G4	R	$12\sqrt{3}$
	B	$\dfrac{16}{15}$		z	–13		x	$\dfrac{7}{4}(=1.75)$		S	$*8$ see the remark
	C	$\dfrac{1}{4}$		s	$\dfrac{1}{4}$		z	30		T	$\dfrac{1}{2}$
	a	1		t	14		R	$\dfrac{15}{4}(=3.75)$		W	2013021

Individual Event 1

I1.1 If a is a real number satisfying $\log_2 (x + 3) - \log_2 (x + 1) = 1$, find the value of a.

$\log_2 \dfrac{x+3}{x+1} = \log_2 2$

$x + 3 = 2x + 2$

$x = 1 \Rightarrow a = 1$

I1.2 In Figure 1, O is the centre of the circle with radius 1 cm. If the length of the arc AB is equal to a cm and the area of the shaded sector OAB is equal to b cm^2, find the value of b. (Take $\pi = 3$)
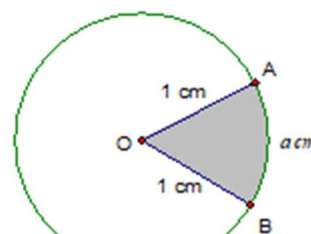
$b = \dfrac{1}{2}rs = \dfrac{1}{2}1 \cdot 1 = \dfrac{1}{2}$

Figure 1

I1.3 An interior angle of a regular C-sided polygon is $288b°$, find the value of C.
Each interior angle $= 288b° = 144°$

Each exterior angle $= 36° = \dfrac{360°}{C}$

$C = 10$

I1.4 Given that C is a root of the equation $kx^2 + 2x + 5 = 0$, where k is a constant. If D is another root, find the value of D.

$100k + 20 + 5 = 0 \Rightarrow k = -\dfrac{1}{4}$

$C + D = \text{sum of roots} = -\dfrac{2}{k}$

$10 + D = 8 \Rightarrow D = -2$

Individual Event 2

I2.1 Given that $a : b : c = 6 : 3 : 1$. If $R = \dfrac{3b^2}{2a^2 + bc}$, find the value of R.

Let $a = 6k$, $b = 3k$, $c = k$, then $R = \dfrac{3(3k)^2}{2(6k)^2 + (3k)k} = \dfrac{9}{25}$

Remark: original question is Given that a, b and c are three numbers not equal to 0 and $a : b :$
$c = 6 : 3 : 1 \cdots\cdots$, the condition $a : b : c = 6 : 3 : 1$ already implies that a, b and c are not zero.

I2.2 Given that $\dfrac{|k + R|}{|R|} = 0$. If $S = \dfrac{|k + 2R|}{|2k + R|}$, find the value of S.

$k + \dfrac{9}{25} = 0 \Rightarrow k = -\dfrac{9}{25}$

$S = \dfrac{|k + 2R|}{|2k + R|} = \dfrac{\left|-\frac{9}{25} + \frac{18}{25}\right|}{\left|-\frac{18}{25} + \frac{9}{25}\right|} = 1$

I2.3 Given that $T = \sin 50° \times (S + \sqrt{3} \times \tan 10°)$, find the value of T.

$T = \sin 50° \times (1 + \sqrt{3} \cdot \dfrac{\sin 10°}{\cos 10°})$

$= \dfrac{\sin 50°}{\cos 10°} \cdot \left(\cos 10° + \sqrt{3} \sin 10°\right)$

$= \dfrac{2 \sin 50°}{\cos 10°} \left(\dfrac{1}{2} \cos 10° + \dfrac{\sqrt{3}}{2} \sin 10°\right)$

$= \dfrac{2 \sin 50°}{\cos 10°} \left(\cos 60° \cdot \cos 10° + \sin 60° \cdot \sin 10°\right)$

$= \dfrac{2 \sin 50° \cos 50°}{\cos 10°} = \dfrac{\sin 100°}{\cos 10°} = 1$

I2.4 Given that x_0 and y_0 are real numbers satisfying the system of equations $\begin{cases} y = \dfrac{T}{x} \\ y = |x| + T \end{cases}$.

If $W = x_0 + y_0$, find the value of W.

$\begin{cases} y = \dfrac{1}{x} \\ y = |x| + 1 \end{cases}$

$\dfrac{1}{x} = |x| + 1 \cdots\cdots(*)$

$\dfrac{1}{x} = x + 1$ or $\dfrac{1}{x} = -x + 1$

$1 = x^2 + x$ or $1 = -x^2 + x$

$x^2 + x - 1 = 0$ or $x^2 - x + 1 = 0$

$x = \dfrac{-1 \pm \sqrt{5}}{2}$ or no solution

Check: sub. $x = \dfrac{-1 - \sqrt{5}}{2}$ into (*)

LHS $= \dfrac{2}{-1 - \sqrt{5}} < 0$, RHS > 0 (rejected)

When $x = \dfrac{-1 + \sqrt{5}}{2}$; LHS $= \dfrac{2}{-1 + \sqrt{5}} = \dfrac{\sqrt{5} + 1}{2}$; RHS $= \dfrac{-1 + \sqrt{5}}{2} + 1 = \dfrac{1 + \sqrt{5}}{2}$ (accepted)

$y = \dfrac{1 + \sqrt{5}}{2} \Rightarrow W = x_0 + y_0 = \dfrac{-1 + \sqrt{5}}{2} + \dfrac{1 + \sqrt{5}}{2} = \sqrt{5}$

Individual Event 3

I3.1 Given that $\dfrac{2x-3}{x^2-x} = \dfrac{A}{x-1} + \dfrac{B}{x}$, where A and B are constants. If $S = A^2 + B^2$, find the value of S

$\dfrac{2x-3}{x^2-x} = \dfrac{Ax + B(x-1)}{(x-1)x}$

$A + B = 2, -B = -3$

$A = -1, B = 3$

$S = (-1)^2 + 3^2 = 10$

I3.2 In Figure 1, $ABCD$ is an inscribed rectangle, $AB = (S-2)$ cm and $AD = (S-4)$ cm. If the circumference of the circle is R cm, find the value of R. (Take $\pi = 3$)

$AB = 8$ cm, $CD = 6$ cm

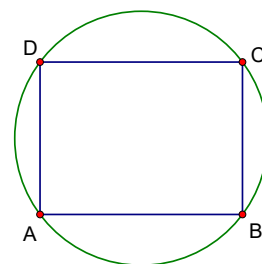$AC = 10$ cm (Pythagoras' theorem)

$R = 10\pi = 30$

Figure 1

I3.3 Given that x and y are integers satisfying the equation $\dfrac{R}{2}xy = 21x + 20y - 13$.

If $T = xy$, find the value of T.

$15xy = 21x + 20y - 13$

$(3x - 4)(5y - 7) = 15$

$\begin{cases} 3x - 4 = 1 \\ 5y - 7 = 15 \end{cases}$ or $\begin{cases} 3x - 4 = 3 \\ 5y - 7 = 5 \end{cases}$ or $\begin{cases} 3x - 4 = 5 \\ 5y - 7 = 3 \end{cases}$ or $\begin{cases} 3x - 4 = 15 \\ 5y - 7 = 1 \end{cases}$ or $\begin{cases} 3x - 4 = -1 \\ 5y - 7 = -15 \end{cases}$ or

$\begin{cases} 3x - 4 = -3 \\ 5y - 7 = -5 \end{cases}$ or $\begin{cases} 3x - 4 = -5 \\ 5y - 7 = -3 \end{cases}$ or $\begin{cases} 3x - 4 = -15 \\ 5y - 7 = -1 \end{cases}$

For integral solution: $3x - 4 = 5, 5y - 7 = 3$

$x = 3, y = 2 \Rightarrow T = 3 \times 2 = 6$

I3.4 Let a be the positive root of the equation $x^2 - 2x - T = 0$.

If $P = 3 + \dfrac{T}{2 + \dfrac{T}{2 + \dfrac{T}{2 + \dfrac{T}{a}}}}$, find the value of P.

$x^2 - 2x - 6 = 0$

$a = 1 + \sqrt{7}$

$a^2 - 2a - 6 = 0 \Rightarrow a^2 = 2a + 6 \Rightarrow a = 2 + \dfrac{6}{a}$

$2 + \dfrac{T}{a} = 2 + \dfrac{6}{a} = a \Rightarrow 2 + \dfrac{T}{2 + \dfrac{T}{a}} = 2 + \dfrac{6}{a} = a \Rightarrow 2 + \dfrac{T}{2 + \dfrac{T}{2 + \dfrac{T}{a}}} = 2 + \dfrac{6}{a} = a$

$P = 3 + \dfrac{6}{a} = 1 + 2 + \dfrac{6}{a} = 1 + a = 1 + 1 + \sqrt{7} = 2 + \sqrt{7}$

Individual Event 4

I4.1 Let $\dfrac{k}{4} = \left(1 + \dfrac{1}{2} + \dfrac{1}{3}\right) \times \left(\dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{4}\right) - \left(1 + \dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{4}\right) \times \left(\dfrac{1}{2} + \dfrac{1}{3}\right)$, find the value of k.

Reference: 1995 FG6.2

Let $x = 1 + \dfrac{1}{2} + \dfrac{1}{3}$, $y = 1 + \dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{4}$, then $\dfrac{k}{4} = x(y-1) - y(x-1) = -x + y = \dfrac{1}{4} \Rightarrow k = 1$

I4.2 Let x and y be real numbers satisfying the equation $y^2 + 4y + 4 + \sqrt{x + y + k} = 0$.

If $r = |xy|$, find the value of r.
Reference: 2005 FI4.1, 2009 FG1.4, 2011 FI4.3, 2013 FI1.4, 2015 HG4, 2015 FI1.1

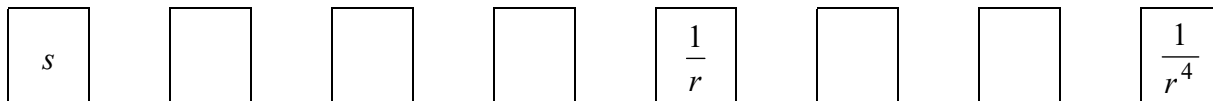The equation is equivalent to $(y + 2)^2 + \sqrt{x + y + k} = 0$

which is a sum of two non-negative numbers.
$\Rightarrow y + 2 = 0$ and $x + y + 1 = 0$
$y = -2$ and $x - 2 + 1 = 0$, $x = 1$
$r = |-2 \times 1| = 2$

I4.3 In Figure 1, there are eight positive numbers in series. Starting from the 3ʳᵈ number, each number is the product of the previous two numbers. Given that the 5ᵗʰ number is $\dfrac{1}{r}$ and the 8ᵗʰ number is $\dfrac{1}{r^4}$. If the first number is s, find the value of s.

s				$\dfrac{1}{r}$			$\dfrac{1}{r^4}$

Let the 2ⁿᵈ number be a, then other numbers are as follows:

s	a	sa	sa^2	$s^2a^3 = \dfrac{1}{r}$	s^3a^5	s^5a^8	$s^8a^{13} = \dfrac{1}{r^4}$
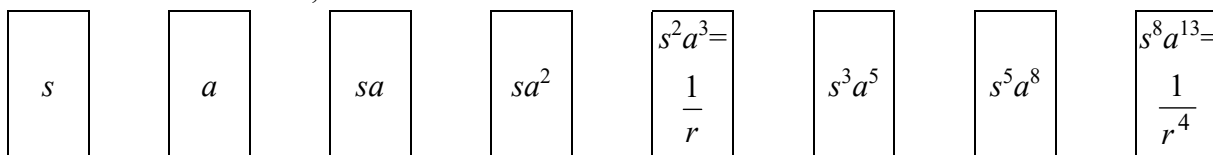
$s^2a^3 = \dfrac{1}{r}$ $\cdots\cdots$ (1)

$s^8a^{13} = \dfrac{1}{r^4}$ $\cdots\cdots$ (2)

(2)÷(1)⁴: $a = 1$

Sub. $a = 1$ into (1): $s^2 = \dfrac{1}{r} = \dfrac{1}{2}$; $s > 0 \Rightarrow s = \dfrac{1}{\sqrt{2}}$

I4.4 Let $[x]$ be the largest integer not greater than x. For example, $[2.5] = 2$.

Let $w = 1 + [10 \times s^2] + [10 \times s^4] + [10 \times s^6] + \cdots + [10 \times s^{2n}] + \cdots$, find the value of w.

$w = 1 + [10 \times \dfrac{1}{2}] + [10 \times \dfrac{1}{4}] + [10 \times \dfrac{1}{8}] + \cdots + [10 \times \dfrac{1}{2^n}] + \cdots$

$= 1 + 5 + 2 + 1 + 0 + 0 + \cdots = 9$

Group Event 1

G1.1 Given that k is a real number. If $x^2 + 2kx - 3k^2$ can be divisible by $x - 1$, find the greatest value of k.

By factor theorem, $1^2 + 2k - 3k^2 = 0$

$3k^2 - 2k - 1 = 0$

$(3k + 1)(k - 1) = 0$

$k = -\dfrac{1}{3}$ or 1

Greatest value of $k = 1$

G1.2 Given that $x = x_0$ and $y = y_0$ satisfy the system of equations $\begin{cases} \dfrac{x}{3} + \dfrac{y}{5} = 1 \\ \dfrac{x}{5} + \dfrac{y}{3} = 1 \end{cases}$. If $B = \dfrac{1}{x_0} + \dfrac{1}{y_0}$, find the value of B.

$\dfrac{x}{3} + \dfrac{y}{5} = \dfrac{x}{5} + \dfrac{y}{3} = 1 \Rightarrow \dfrac{x}{3} - \dfrac{x}{5} = \dfrac{y}{3} - \dfrac{y}{5} \Rightarrow x = y$

Sub. $x = y$ into the first equation: $\dfrac{x}{3} + \dfrac{x}{5} = 1 \Rightarrow x = y = \dfrac{15}{8} \Rightarrow B = \dfrac{16}{15}$

G1.3 Given that $x = 2 + \sqrt{3}$ is a root of the equation $x^2 - (\tan \alpha + \cot \alpha)x + 1 = 0$.

If $C = \sin \alpha \times \cos \alpha$, find the value of C.

Let the other root be y, $(2 + \sqrt{3})y = $ product of roots $= 1 \Rightarrow y = 2 - \sqrt{3}$

$\tan \alpha + \cot \alpha = $ sum of roots $= 2 + \sqrt{3} + 2 - \sqrt{3} = 4$

$\dfrac{\sin \alpha}{\cos \alpha} + \dfrac{\cos \alpha}{\sin \alpha} = 4 \Rightarrow \dfrac{1}{\sin \alpha \cos \alpha} = 4 \Rightarrow C = \sin \alpha \times \cos \alpha = \dfrac{1}{4}$

G1.4 Let a be an integer. If the inequality $|x + 1| < a - 1.5$ has no integral solution, find the greatest value of a.

$\because |x + 1| \geq 0$, In order that the equation has no integral solution, it is sufficient that $a - 1.5 < 0$

$a < 1.5$

Greatest integral value of $a = 1$

Group Event 2
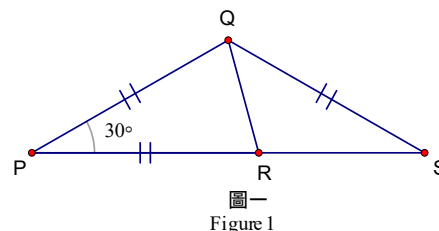
G2.1 In Figure 1, PRS is a straight line, $PQ = PR = QS$ and $\angle QPR = 30°$. If $\angle RQS = w°$, find the value of w.

$\angle QPR = \angle QSP = 30°$ (base $\angle$s isos. Δ)

$\angle PQS = 120°$ ($\angle$s sum of Δ)

$\angle PQR = \angle PRQ = (180° - 30°) \div 2 = 75°$ ($\angle$s sum of isos. Δ)

$\angle RQS = 120° - 75° = 45° \Rightarrow w = 45$

圖一
Figure 1

G2.2 Let $f(x) = px^7 + qx^3 + rx - 5$, where p, q and r are real numbers.

If $f(-6) = 3$ and $z = f(6)$, find the value of z.

Reference: 1995 FI1.3

$f(-6) = 3 \Rightarrow -p \times 6^7 - q \times 6^3 - 6r - 5 = 3$

$f(6) = p \times 6^7 + q \times 6^3 + 6r - 5 = -(-p \times 6^7 - q \times 6^3 - 6r - 5) - 10 = -3 - 10 = -13$

G2.3 If $n \neq 0$ and $s = \left(\dfrac{20}{2^{2n+4} + 2^{2n+2}} \right)^{\frac{1}{n}}$, find the value of s.

$s = \left(\dfrac{20}{16 \cdot 2^{2n} + 4 \cdot 2^{2n}} \right)^{\frac{1}{n}} = \left(\dfrac{20}{20 \cdot 2^{2n}} \right)^{\frac{1}{n}} = \dfrac{1}{4}$

G2.4 Given that x and y are positive integers and $x + y + xy = 54$. If $t = x + y$, find the value of t.

Reference: 2024 FI1.1

$1 + x + y + xy = 55$

$(1 + x)(1 + y) = 55$

$1 + x = 5, 1 + y = 11$ or $1 + x = 11, 1 + y = 5$

$x = 4, y = 10$ or $x = 10, y = 4$

$t = 14$

Group Event 3

G3.1 Given that $r = 2006 \times \dfrac{\sqrt{8} - \sqrt{2}}{\sqrt{2}}$, find the value of r.

It is easy to show that $r = 2006$.

G3.2 Given that $6^{x+y} = 36$ and $6^{x+5y} = 216$, find the value of x.

$x + y = 2$ .... (1)

$x + 5y = 3$ .... (2)

$5(1) - (2)$: $4x = 7 \Rightarrow x = \dfrac{7}{4}$

G3.3 Given that $\tan x + \tan y + 1 = \cot x + \cot y = 6$. If $z = \tan(x + y)$, find the value of z.

$\tan x + \tan y + 1 = \dfrac{\tan y + \tan x}{\tan x \tan y} = 6$

$\tan x + \tan y = 5$; $\tan x \tan y = \dfrac{5}{6}$

$\tan(x + y) = \dfrac{\tan x + \tan y}{1 - \tan x \tan y} = \dfrac{5}{1 - \frac{5}{6}} = 30$

G3.4 In Figure 1, $ABCD$ is a rectangle, F is the midpoint of CD and $BE : EC = 1 : 3$. If the area of the rectangle $ABCD$ is 12 cm^2 and the area of $BEFD$ is R cm^2, find the value of R.

Area of $\Delta BCD = 6$ cm^2

Area of $\Delta CEF = \dfrac{3}{4} \cdot \dfrac{1}{2} \cdot 6 \text{ cm}^2 = \dfrac{9}{4}$ cm^2

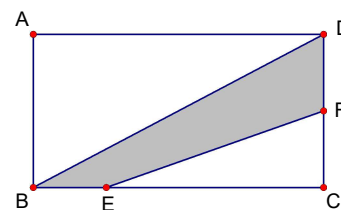Area of $BEFD = (6 - \dfrac{9}{4})$ cm$^2 = \dfrac{15}{4}$ cm^2

Figure 1

Group Event 4

G4.1 In Figure 1, $ABCD$ is a parallelogram, $BE \perp CD$, $BF \perp AD$,
$CE = 2$ cm, $DF = 1$ cm and $\angle EBF = 60°$.
If the area of the parallelogram $ABCD$ is R cm^2,
find the value of R.

$\angle EDF = 360° - 90° - 90° - 60° = 120°$ ($\angle$s sum of polygon)
$\angle BAD = \angle BCD = 180° - 120° = 60°$ (int. $\angle$s //-lines)

$BC = \dfrac{2}{\cos 60°}$ cm $= 4$ cm $= AD$

$BE = 2 \tan 60° = 2\sqrt{3}$ cm
$AF = (4 - 1)$ cm $= 3$ cm

$AB = \dfrac{3}{\cos 60°}$ cm $= 6$ cm

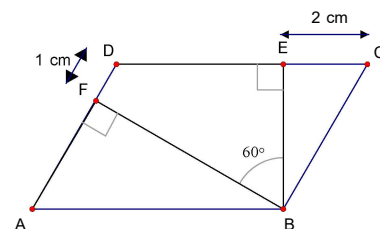Area of $ABCD = AB \times BE = 6 \times 2\sqrt{3}$ cm$^2 = 12\sqrt{3}$ cm^2

G4.2 Given that a and b are positive numbers and $a + b = 2$. If $S = \left(a + \dfrac{1}{a}\right)^2 + \left(b + \dfrac{1}{b}\right)^2$,

find the minimum value S. **Reference: HKAL Pure Mathematics 1964 Paper 1 Q5 (b)**

$\left(\sqrt{a} - \sqrt{b}\right)^2 \geq 0 \Rightarrow a + b - 2\sqrt{ab} \geq 0 \Rightarrow 1 \geq \sqrt{ab} \Rightarrow 1 \geq ab \cdots\cdots$ (1)

$a^2 + b^2 = (a + b)^2 - 2ab = 4 - 2ab \geq 4 - 2 = 2 \cdots\cdots$ (2)

$\dfrac{1}{ab} \geq 1 \Rightarrow \dfrac{1}{a^2 b^2} \geq 1 \cdots\cdots$ (3)

$S = \left(a + \dfrac{1}{a}\right)^2 + \left(b + \dfrac{1}{b}\right)^2 = a^2 + b^2 + \dfrac{1}{a^2} + \dfrac{1}{b^2} + 4$

$= a^2 + b^2 + \dfrac{a^2 + b^2}{a^2 b^2} + 4$

$= \left(a^2 + b^2\right)\left(1 + \dfrac{1}{a^2 b^2}\right) + 4$

$\geq 2 \times (1 + 1) + 4 = 8$ (by (2) and (3))

Remark: original question $\cdots$ a and b are positive real numbers $\cdots$

Positive numbers must be real, there is no need to emphasise the word 'real'.

G4.3 Let $2^x = 7^y = 196$. If $T = \dfrac{1}{x} + \dfrac{1}{y}$, find the value of T.

Reference: 2001 HI1, 2003 FG2.2, 2004 FG4.3, 2005 HI9

$x \log 2 = y \log 7 = \log 196$

$x = \dfrac{\log 196}{\log 2}, y = \dfrac{\log 196}{\log 7}$

$T = \dfrac{1}{x} + \dfrac{1}{y} = \dfrac{\log 2 + \log 7}{\log 196} = \dfrac{\log 14}{\log 14^2} = \dfrac{1}{2}$

Method 2 (provided by Denny)

$2 = 196^{\frac{1}{x}}, 7 = 196^{\frac{1}{y}}$

$2 \times 7 = 14 = \sqrt{196} = 196^{\frac{1}{x}} \times 196^{\frac{1}{y}} = 196^{\frac{1}{x} + \frac{1}{y}}$

$\dfrac{1}{x} + \dfrac{1}{y} = \dfrac{1}{2}$

G4.4 If $W = 2006^2 - 2005^2 + 2004^2 - 2003^2 + \ldots + 4^2 - 3^2 + 2^2 - 1^2$, find the value of W.

$W = (2006 + 2005)(2006 - 2005) + (2004 + 2003)(2004 - 2003) + \cdots + (4 + 3)(4 - 3) + (2 + 1)(2 - 1)$

$= 2006 + 2005 + 2004 + \ldots + 4 + 3 + 2 + 1$

$= \dfrac{2006}{2}(2006 + 1) = 1003 \times 2007 = 2013021$