2017 – 2018 Log1 Contest Round 1

Theta Functions

Name: _____

Units do not have to be included.

4 points each		
1	If $h(x) = 3x + 2$, find the value of x when $h(x) = 8$.	
2	The function for the volume of a right cylindrical cone is $V(h) = \frac{1}{3}\pi r^2 h$. Calculate the height of this cone if its volume is $\frac{32}{3}\pi$ and its radius is 2.	
3	If $g(x) = 5x - 3$ and $k(x) = 2x$, evaluate $g(k(2))$	
4	Let $f(x) = 3x^2 - 2$ and $g(x) = 4x + 1$. Determine the value of $h(2)$ if the function $h(x) = \sqrt{f(x)^{g(x)}}$. Reduce the answer into the simplest root form. Note that $g(x)$ is an exponent of $f(x)$.	
5	Let $f(x) = x^3 - 2x^2 - x + 2$. If $(x + 1)$ is a factor of $f(x)$, then find the sum of all the roots.	

5 points each		
6	Kate throws a ball off a 126 foot cliff with an initial upward velocity of 8 feet/sec. The height of the ball t seconds after it is thrown is given by the function $$h(t) = -16t^2 + 8t + 126$$ Find the maximum height of the ball in feet.	
7	Given two numbers, a and b, determine the sum of their cubes if $a + b = 3$ and $a^2 + b^2 = 6$. In other words, calculate $a^3 + b^3$.	
8	Consider the 2 functions shown below. $$f(x) = 12x^2 - 8x + 18$$ $$g(x) = 5\log_{10} 2x$$ Evaluate $f(g(f(2)))$	
9	Determine the equation(s) for the vertical asymptote(s) of the function $$f(x) = \frac{2x^2 + x - 15}{x^2 - 3x - 4}$$	
10	Find the minimum value of $f(x) = 10x^2 - 2x - 5$	

6 points each		
11	If $f(x) = \frac{x+6}{x-5}$, find $f^{-1}(x)$	
12	Let f(x) be a function as expressed below. $$f(x) = \frac{x+4}{x-2}$$ Determine the expression for f(f(f(x))).	
13	Find the coefficient of the 7th-degree term in the expansion of $(3x + 2)^{11}$. You may express your answer as a product of positive factors if you desire.	
14	Find all the roots of the function $$f(x) = x^3 + 5x^2 + 9x + 5$$	
15	Let $f(x) = x^3 + 11x^2 + 3x - 135$. If the three roots of f(x) are a, b, and c, what is the maximum value of $a - b + c$.	

2017 – 2018 Log1 Contest Round 1

Alpha Functions

Name: _____

Units do not have to be included.

4 points each		
1	If $h(x) = 3x + 2$, find the value of x when $h(x) = 8$.	
2	The function for the volume of a right cylindrical cone is $V(h) = \frac{1}{3}\pi r^2 h$. Calculate the height of this cone if its volume is $\frac{32}{3}\pi$ and its radius is 2.	
3	If $g(x) = 5x - 3$ and $k(x) = 2x$, evaluate $g(k(2))$	
4	Compute the limit for the following function. $$\lim_{x \to 0} \frac{x^2 + 6x}{x}$$	
5	Let $f(x) = x^3 - 2x^2 - x + 2$. If $(x + 1)$ is a factor of $f(x)$, then find the sum of all the roots.	

5 points each		
6	Kate throws a ball off a 126 foot cliff with an initial upward velocity of 8 feet/sec. The height of the ball t seconds after it is thrown is given by the function $$h(t) = -16t^2 + 8t + 126$$ Find the maximum height of the ball in feet.	
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8	Consider the 2 functions shown below. $$f(x) = 12x^2 - 8x + 18$$ $$g(x) = 5\log_{10} 2x$$ Evaluate $f(g(f(2)))$	
9	Let $f(x) = (\sin x + \cos x)^2$. Evaluate the inverse function $f^{-1}(\frac{3}{2})$ on the domain $\left[0, \frac{\pi}{2}\right]$.	
10	Find the minimum value of $f(x) = 10x^2 - 2x - 5$	

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11	If $f(x) = \frac{x+6}{x-5}$, find $f^{-1}(x)$	
12	Let f(x) be a function as expressed below. $$f(x) = \frac{x+4}{x-2}$$ Determine the expression for f(f(f(x))).	
13	Find the coefficient of the 7th-degree term in the expansion of $(3x + 2)^{11}$. You may express your answer as a product of positive factors if you desire.	
14	Suppose $f(x) = e^x$, $g(x) = a \ln x$, and $h(x) = be^x$ Let $h(1) = a$ and $f \circ g \circ h(1) = e^b$ Calculate the exact values for ln a and ln b.	
15	Let $f(x) = x^3 + 11x^2 + 3x - 135$. If the three roots of f(x) are a, b, and c, what is the maximum value of $a - b + c$.	

2017 – 2018 Log1 Contest Round 1

Mu Functions

Name: _____

Units do not have to be included.

	4 points each	
1	If $h(x) = 3x + 2$, find the value of x when $h(x) = 8$.	
2	The function for the volume of a right cylindrical cone is $V(h) = \frac{1}{3}\pi r^2 h$. Calculate the height of this cone if its volume is $\frac{32}{3}\pi$ and its radius is 2.	
3	If $g(x) = 5x - 3$ and $k(x) = 2x$, evaluate $g(k(2))$	
4	Compute the limit for the following function. $$\lim_{x \to 0} \frac{x^2 + 6x}{x}$$	
5	Given the function $f(x) = x^2 + 3e^{3x} + 2$, evaluate $f'(\ln 2)$.	

	5 points each	
6	Kate throws a ball off a 126 foot cliff with an initial upward velocity of 8 feet/sec. The height of the ball t seconds after it is thrown is given by the function $$h(t) = -16t^2 + 8t + 126$$ Find the maximum height of the ball in feet.	
7	Given two numbers, a and b, determine the sum of their cubes if $a + b = 3$ and $a^2 + b^2 = 6$. In other words, calculate $a^3 + b^3$.	
8	Consider the 2 functions shown below. $$f(x) = 12x^2 - 8x + 18$$ $$g(x) = 5\log_{10} 2x$$ Evaluate $f(g(f(2)))$	
9	Let $f(x) = (\sin x + \cos x)^2$. Evaluate the inverse function $f^{-1}(\frac{3}{2})$ on the domain $\left[0, \frac{\pi}{2}\right]$.	
10	Let $f(x) = \sin(6x)\cos(3x)$ and $g(x) = \frac{1}{3}x$ Evaluate the definite integral shown below. $$\int_0^{\frac{\pi}{2}} (f \circ g(x))dx$$	

6 points each		
11	If $f(x) = \frac{x+6}{x-5}$, find $f^{-1}(x)$	
12	Let f(x) be a function as expressed below. $$f(x) = \frac{x+4}{x-2}$$ Determine the expression for f(f(f(x))).	
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15	Let $f(x) = \cos x \tan^3 x$ and $g(x) = \int f(x)dx$. If $g(0) = 2$ and $h(x) = g^{-1}(x)$, determine all possible values of $h\left(-\frac{5}{2}\right)$ within the interval $[0,2\pi]$.	

2017 – 2018 Log1 Contest Round 1

Theta Functions – Answer Key

Name: _____

Units do not have to be included.

4 points each		
1	If $h(x) = 3x + 2$, find the value of x when $h(x) = 8$.	2
2	The function for the volume of a right cylindrical cone is $V(h) = \frac{1}{3}\pi r^2 h$. Calculate the height of this cone if its volume is $\frac{32}{3}\pi$ and its radius is 2.	8
3	If $g(x) = 5x - 3$ and $k(x) = 2x$, evaluate $g(k(2))$	17
4	Let $f(x) = 3x^2 - 2$ and $g(x) = 4x + 1$. Determine the value of $h(2)$ if the function $h(x) = \sqrt{f(x)^{g(x)}}$. Reduce the answer into the simplest root form. Note that $g(x)$ is an exponent of $f(x)$.	$10000\sqrt{10}$
5	Let $f(x) = x^3 - 2x^2 - x + 2$. If $(x + 1)$ is a factor of $f(x)$, then find the sum of all the roots.	2

5 points each		
6	Kate throws a ball off a 126 foot cliff with an initial upward velocity of 8 feet/sec. The height of the ball t seconds after it is thrown is given by the function $$h(t) = -16t^2 + 8t + 126$$ Find the maximum height of the ball in feet.	127
7	Given two numbers, a and b, determine the sum of their cubes if $a + b = 3$ and $a^2 + b^2 = 6$. In other words, calculate $a^3 + b^3$.	$\frac{27}{2}$
8	Consider the 2 functions shown below. $$f(x) = 12x^2 - 8x + 18$$ $$g(x) = 5\log_{10} 2x$$ Evaluate $f(g(f(2)))$	1138
9	Determine the equation(s) for the vertical asymptote(s) of the function $$f(x) = \frac{2x^2 + x - 15}{x^2 - 3x - 4}$$	$x = 4$ $x = -1$
10	Find the minimum value of $f(x) = 10x^2 - 2x - 5$	$-\frac{51}{10}$ *or* -5.1

6 points each		
11	If $f(x) = \frac{x+6}{x-5}$, find $f^{-1}(x)$	$\frac{5x+6}{x-1}$
12	Let f(x) be a function as expressed below. $f(x) = \frac{x+4}{x-2}$ Determine the expression for f(f(f(x))).	$\frac{x+28}{7x-20}$
13	Find the coefficient of the 7th-degree term in the expansion of $(3x+2)^{11}$. You may express your answer as a product of positive factors if you desire.	$2^5 3^8 5 * 11$ Or 11,547,360
14	Find all the roots of the function $f(x) = x^3 + 5x^2 + 9x + 5$	$x = -1$ $x = -2 + i$ $x = -2 - i$
15	Let $f(x) = x^3 + 11x^2 + 3x - 135$. If the three roots of f(x) are a, b, and c, what is the maximum value of $a - b + c$.	7

2017 – 2018 Log1 Contest Round 1

Alpha Functions – Answer Key

Name: _____

Units do not have to be included.

	4 points each	
1	If $h(x) = 3x + 2$, find the value of x when $h(x) = 8$.	2
2	The function for the volume of a right cylindrical cone is $V(h) = \frac{1}{3}\pi r^2 h$. Calculate the height of this cone if its volume is $\frac{32}{3}\pi$ and its radius is 2.	8
3	If $g(x) = 5x - 3$ and $k(x) = 2x$, evaluate $g(k(2))$	17
4	Compute the limit for the following function. $$\lim_{x \to 0} \frac{x^2 + 6x}{x}$$	6
5	Let $f(x) = x^3 - 2x^2 - x + 2$. If $(x + 1)$ is a factor of $f(x)$, then find the sum of all the roots.	2

	5 points each	
6	Kate throws a ball off a 126 foot cliff with an initial upward velocity of 8 feet/sec. The height of the ball t seconds after it is thrown is given by the function $$h(t) = -16t^2 + 8t + 126$$ Find the maximum height of the ball in feet.	127
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9	Let $f(x) = (\sin x + \cos x)^2$. Evaluate the inverse function $f^{-1}(\frac{3}{2})$ on the domain $\left[0, \frac{\pi}{2}\right]$.	$\frac{\pi}{12}, \frac{5\pi}{12}$
10	Find the minimum value of $f(x) = 10x^2 - 2x - 5$	$-\frac{51}{10}$ or -5.1

6 points each		
11	If $f(x) = \frac{x+6}{x-5}$, find $f^{-1}(x)$	$\frac{5x+6}{x-1}$
12	Let f(x) be a function as expressed below. $f(x) = \frac{x+4}{x-2}$ Determine the expression for f(f(f(x))).	$\frac{x+28}{7x-20}$
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14	Suppose $f(x) = e^x$, $g(x) = a \ln x$, and $h(x) = be^x$ Let $h(1) = a$ and $f \circ g \circ h(1) = e^b$ Calculate the exact values for ln a and ln b.	$\ln b = e^{-1} - 1$ $\ln a = e^{-1}$
15	Let $f(x) = x^3 + 11x^2 + 3x - 135$. If the three roots of f(x) are a, b, and c, what is the maximum value of $a - b + c$.	7

2017 – 2018 Log1 Contest Round 1

Mu Functions – Answer Key

Name: _____

Units do not have to be included.

4 points each		
1	If $h(x) = 3x + 2$, find the value of x when $h(x) = 8$.	2
2	The function for the volume of a right cylindrical cone is $V(h) = \frac{1}{3}\pi r^2 h$. Calculate the height of this cone if its volume is $\frac{32}{3}\pi$ and its radius is 2.	8
3	If $g(x) = 5x - 3$ and $k(x) = 2x$, evaluate $g(k(2))$	17
4	Compute the limit for the following function. $$\lim_{x\to 0} \frac{x^2 + 6x}{x}$$	6
5	Given the function $f(x) = x^2 + 3e^{3x} + 2$, evaluate $f'(\ln 2)$.	$2\ln 2 + 72$ Or $\ln 4 + 72$

5 points each		
6	Kate throws a ball off a 126 foot cliff with an initial upward velocity of 8 feet/sec. The height of the ball t seconds after it is thrown is given by the function $$h(t) = -16t^2 + 8t + 126$$ Find the maximum height of the ball in feet.	127
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10	Let $f(x) = \sin(6x)\cos(3x)$ and $g(x) = \frac{1}{3}x$ Evaluate the definite integral shown below. $$\int_0^{\frac{\pi}{2}} (f \circ g(x))dx$$	$\frac{2}{3}$

6 points each		
11	If $f(x) = \frac{x+6}{x-5}$, find $f^{-1}(x)$	$\frac{5x+6}{x-1}$
12	Let f(x) be a function as expressed below. $f(x) = \frac{x+4}{x-2}$ Determine the expression for f(f(f(x))).	$\frac{x+28}{7x-20}$
13	Find the coefficient of the 7th-degree term in the expansion of $(3x+2)^{11}$. You may express your answer as a product of positive factors if you desire.	$2^5 * 3^8 * 5 * 11$ Or 11,547,360
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15	Let $f(x) = \cos x \tan^3 x$ and $g(x) = \int f(x)dx$. If $g(0) = 2$ and $h(x) = g^{-1}(x)$, determine all possible values of $h\left(-\frac{5}{2}\right)$ within the interval $[0,2\pi]$.	$\left(\frac{2}{3}\pi, \frac{4}{3}\pi\right)$

2017 – 2018 Log1 Contest Round 1
Functions Solutions

Mu	Al	Th	Solution
1	1	1	$8 = 3x + 2$ $3x = 6$ $x = 2$
2	2	2	Set $V(h) = \frac{32}{3}\pi$. Solve for h. $\frac{32}{3}\pi = \frac{1}{3}\pi 2^2 h$ $h = 8$
3	3	3	$k(2) = 2(2) = 4$ $g(k(2)) = g(4) = 5(4) - 3 = 17$
4	4		$\lim_{x\to 0} \frac{x^2+6x}{x} = \lim_{x\to 0} \frac{x(x+6)}{x} = \lim_{x\to 0} x + 6 = 6$
		4	$h(2) = \sqrt{10^9} = \sqrt{10^8 * 10} = 10^4\sqrt{10} = 10000\sqrt{10}$
5			$f'(x) = 2x + 9e^{3x}$ $f'(\ln 2) = 2\ln 2 + 9e^{3(\ln 2)}$ $f'(\ln 2) = 2\ln 2 + 9(e^{\ln 2})^3$ $f'(\ln 2) = 2\ln 2 + 9 * 2^3 = 2\ln 2 + 72$
	5	5	Factoring out $(x + 1)$ from f(x) results in $f(x) = (x + 1)(x^2 - 3x + 2)$ $f(x) = (x + 1)(x - 1)(x - 2)$ The three roots are -1, 1 and 2. The sum of all three roots is 2 Alternatively, the sum of the roots for a cubic has the same form as that for a quadratic, $-\frac{b}{a}$ when $f(x) = ax^3 + bx^2 + cx + d$

6	6	6	The vertex is defined at the point (h, k) when the equation for the parabola is written in vertex form. $$h = -\frac{b}{2a} = -\frac{8}{-32} = \frac{1}{4}$$ The value at k would be the maximum height. $$k = f(0.25) = -16(0.25^2) + 8(0.25) + 126$$ $$k = 127$$ Starting from basic principles. The equation in vertex form is $4p(y-k) = (x-h)^2$. Expand. $$y - k = \frac{1}{4p}x^2 - \frac{h}{2p}x - \frac{h^2}{4p}$$ $$y = \frac{1}{4p}x^2 - \frac{h}{2p}x - \frac{h^2}{4p} + k$$ Thus, $$\frac{1}{4p} = -16 \rightarrow p = -\frac{1}{64}$$ $$-\frac{h}{2p} = 8 \rightarrow h = \frac{1}{4}$$ $$k - \frac{h^2}{4p} = 126 \rightarrow k = 126 + 1 = 127$$
7	7	7	Expand $(a+b)^3 = 3^3 = 27$ $$a^3 + 3a^2b + 3ab^2 + b^3 = 27$$ Factor out 3ab. $$a^3 + 3ab(a+b) + b^3 = 27$$ $$a^3 + b^3 = 27 - 3ab(a+b) = 27 - 9ab$$ Evaluate ab. $$(a+b)^2 = a^2 + 2ab + b^2 = 3^2 = 9$$ $$ab = \frac{9 - (a^2 + b^2)}{2} = \frac{9-6}{2} = \frac{3}{2}$$ $$a^3 + b^3 = 27 - 9 * \left(\frac{3}{2}\right) = \frac{27}{2}$$
8	8	8	$$f(2) = 12(2^2) - 8(2) + 18 = 50$$ $$g(50) = 5\log_{10} 2(50) = 5\log_{10} 100 = 5(2) = 10$$ $$f(10) = 12(10)^2 - 8(10) + 18 = 1200 - 80 + 18$$ $$f(10) = 1138$$

9	9		Set $f(x) = \frac{3}{2}$ and solve for x $$\frac{3}{2} = (\sin x + \cos x)^2$$ $$\frac{3}{2} = 1 + \sin 2x$$ $$\sin 2x = \frac{1}{2}$$ $$x = \frac{\pi}{12}, \frac{5\pi}{12}$$
		9	Factor the numerator and denominator: $$f(x) = \frac{(x+3)(2x-5)}{(x+1)(x-4)}$$ Vertical asymptote at $x = 4$ and $x = -1$
10			$$f \circ g(x) = \sin\left(6\left(\frac{1}{3}x\right)\right)\cos\left(3\left(\frac{1}{3}x\right)\right)$$ $$f \circ g(x) = \sin(2x)\cos(x)$$ $$f \circ g(x) = 2\sin x \cos^2 x$$ $$\int_0^{\frac{\pi}{2}} (f \circ g(x))dx = 2\sin x \cos^2 x \, dx$$ $$u = \cos x \qquad du = -\sin x \, dx$$ $$-2du = 2\sin x \, dx$$ $$\int_1^0 -2u^2 \, du = -\frac{2}{3}0^3 - (-\frac{2}{3}(1)^3) = \frac{2}{3}$$
	10	10	The x-coordinate of the parabola's vertex is located at $$x = -\frac{b}{2a} = -\frac{-2}{2(10)} = \frac{1}{10}$$ Since the parabola is concave upward, evaluate $f\left(\frac{1}{10}\right)$. $$f\left(\frac{1}{10}\right) = 10\left(\frac{1}{10}\right)^2 - 2\left(\frac{1}{10}\right) - 5$$ $$f_{min} = \frac{10}{100} - \frac{20}{100} - \frac{500}{100}$$ $$f_{min} = -\frac{510}{100} = -\frac{51}{10}$$

11	11	11	Setup the inverse function in the following way. $$x = \frac{y+6}{y-5}$$ Solve for y. $$x(y-5) = y+6 \rightarrow yx - 5x = y+6$$ $$yx - y = 5x + 6$$ $$y(x-1) = 5x+6$$ $$f^{-1}(x) = \frac{5x+6}{x-1}$$
12	12	12	$$f(f(x)) = \frac{\frac{x+4}{x-2}+4}{\frac{x+4}{x-2}-2} = \frac{x+4+4x-8}{x+4-2x+4} = \frac{5x-4}{-x+8}$$ $$f\Big(f\big(f(x)\big)\Big) = \frac{\left(\frac{5x-4}{-x+8}\right)+4}{\frac{5x-4}{-x+8}-2} = \frac{5x-4-4x+32}{5x-4+2x-16}$$ $$f(f\big(f(x)\big) = \frac{x+28}{7x-20}$$
13	13	13	The binomial expansion theorem gives the 7^{th} degree term as $$\binom{11}{4}(3x)^7(2)^4$$ Evaluating: $$\frac{11*10*9*8}{4*3*2} * 3^7 * 2^4$$ $$2^4 * 3^7 * 3 * 10 * 11 = 11{,}547{,}360$$
14	14		Since $h(1) = a$, it follows that $a = be$. Evaluate the composite function $f \circ g \circ h(1)$. $$g \circ h(1) = g(a) = a\ln(be)$$ $$f \circ g \circ h(1) = f(a\ln(be)) = e^{a\ln(be)} = e^b$$ $$b = a\ln(be)$$ $$b = be\ln(be)$$ $$1 = e(\ln b + \ln(e)) = e(\ln b + 1)$$ $$\ln b = e^{-1} - 1$$ $$\ln a = \ln(be) = \ln b + \ln e = \ln b + 1$$ $$\ln a = e^{-1} - 1 + 1$$ $$\ln a = e^{-1}$$

		14	A factor could potentially by $(x \pm p)$ where p are the possible factors of 5. It turns out that $(x + 1)$ is a factor. $$f(x) = (x + 1)(x^2 + 4x + 5)$$ Setting to 0: $$0 = (x + 1)(x^2 + 4x + 5)$$ One root of the function is $$x = -1$$ The other roots are found from the quadratic factor. $$\frac{-4 \pm \sqrt{16 - 4(1)(5)}}{2(1)} = -2 \pm \frac{\sqrt{-4}}{2} = -2 \pm i$$
	15	15	The function f(x) can be written as $$f(x) = (x + 9)(x - 3)(x + 5)$$ Thus, the roots are -9, 3, and -5. To maximize $a - b + c$, we need to make *b* the smallest root. Hence, $$a - b + c = 3 - (-9) - 5 = 7$$

15			Integrate f(x) $g(x) = \int f(x)dx = g(x) = \int \cos x \tan^3 x \, dx$ $g(x) = \int \cos x \tan x \tan^2 x \, dx$ $g(x) = \int \sin x(\sec^2 x - 1) \, dx$ $g(x) = \int \sin x \, (\cos x)^{-2} \, dx - \int \sin x \, dx$ $u = \cos x \;\; du = -\sin x \, dx$ $g(x) = \int -u^{-2} \, du - \int \sin x \, dx$ $g(x) = u^{-1} + \cos x + C$ $g(x) = (\cos x)^{-1} + \cos x + C$ $g(0) = (1)^{-1} + 1 + C = 2$ $C = 0$ Express $g^{-1}(x)$ as $x = (\cos y)^{-1} + \cos y$ $-\frac{5}{2} = (\cos y)^{-1} + \cos y$ $-\frac{5}{2} = \frac{\cos^2 y + 1}{\cos y}$ $-\frac{5}{2}\cos y = \cos^2 y + 1 \rightarrow 0 = 2\cos^2 y + 5\cos y + 2$ $\cos y = \frac{\left[-5 \pm \sqrt{25 - 4(2)(2)}\right]}{2 * 2}$ $\cos y = -\frac{5}{4} \pm \frac{3}{4}; \cos y = (-2, -\frac{1}{2})$ $y = h\left(-\frac{5}{2}\right) = \left(\frac{2}{3}\pi, \frac{4}{3}\pi\right)$