Evaluating Logarithms WS **Name** ____________________________

Evaluate each logarithm *without using a calculator*.

1. $\log_5 125 =$ ________
2. $\log_{11} 11 =$ ________
3. $\log_8 1 =$ ________
4. $\log_3 81 =$ ________
5. $\log_9 81 =$ ________
6. $\log_8 1 =$ ________
7. $\log_3 27 =$ ________
8. $\log_4 64 =$ ________
9. $\log 100 =$ ________
10. $\log_8 64 =$ ________
11. $\log_3 9 =$ ________
12. $\log_7 7 =$ ________
13. $\log_2 8 =$ ________
14. $\log_4 256 =$ ________
15. $\log_7 49 =$ ________
16. $\log_2 16 =$ ________
17. $\log_5 625 =$ ________
18. $\log 10{,}000 =$ ________

Now … stretch your mind … the log values don't have to be whole numbers!

19. $\log_{16} 4 =$ ________
20. $\log_8 2 =$ ________
21. $\log_{1/4} 64 =$ ________
22. $\log_{1/3} 81 =$ ________

Inverse Log Properties

$g(x) = \log_b x$ and $f(x) = b^x$ are inverses.

so ...

$\log_b b^x = x$ $\quad b^{\log_b x} = x$

Simplify the expression.

a. $5^{\log_5 x}$

b. $\log_4 4^x$

c. $3^{\log_3 25}$

d. $\log_5 125$

e. $10^{\log x}$

f. $\log 1000^x$

Finding Inverses of Exponential Functions WS

GPS Advanced Algebra

Name________________________

For each of the following, find the inverse.

1. $f(x)=3^x$	2. $f(x)=3^x+4$
3. $f(x)=3^{x-2}$	4. $f(x)=3^{x+3}-5$
5. $g(x)=\left(\frac{1}{2}\right)^x+8$	6. $f(x)=e^{x+3}$
7. $f(x)=e^x-4$	8. $h(x)=e^{x+2}-3$

WHEN LUMBERJACKS PLAY MUSIC, WHY DO THEY USE A LARGE SOUP CAN INSTEAD OF A BASS DRUM?

Logarithms are exponents.

If $\log_b(a) = x$, then $b^x = a$. $\log_2(8) = 3$ because $2^3 = 8$.

Match each logarithmic expression with the value of x.

1) $\log_2 4 = x$	2) $\log_2 x = 3$	3) $\log_4 64 = x$	4) $\log_2 64 = x$
5) $\log_x 81 = 2$	6) $\log_5 x = 2$	7) $\log_x 7 = 1$	8) $\log_4 x = -\frac{1}{2}$
9) $\log_8 x = \frac{1}{3}$	10) $\log_7 x = -1$	11) $\log_{64} x = \frac{1}{2}$	12) $\log_5 x = 4$
13) $\log_3\left(\frac{1}{3}\right) = x$	14) $\log_x 1000 = 3$	15) $\log_{5/2}\left(\frac{2}{5}\right) = x$	16) $\log_5 1 = x$
17) $\log_x 4 = \frac{2}{3}$	18) $\log_2\left(\frac{1}{4}\right) = x$	19) $\log_2 x = 0$	20) $\log_8 x = -\frac{2}{3}$
21) $\log_{1/2} x = -1$	22) $\log_{10} 10^8 = x$	23) $\log_4 x = 1$	24) $\log_{16} x = \frac{1}{2}$
25) $\log_{13} 169 = x$	26) $\log_x 125 = \frac{3}{4}$	27) $\log_{\sqrt{3}} x = 2$	28) $\log_{1/3} x = -2$
29) $\log_{2/3}\left(\frac{9}{4}\right) = x$	30) $\log_x 0.1 = -1$	31) $\log_{81} x = \frac{1}{4}$	32) $\log_x 5 = \frac{1}{2}$
33) $\log_x\left(\frac{1}{4}\right) = -1$	34) $\log_a 1 = x$	35) $\log_a a = x$	36) $\log_x .001 = -3$

Answers

A. 2	B. 6	C. $\frac{1}{7}$	D. 11	E. 4	F. −4	G. 625	H. 0	I. $\frac{1}{2}$	J. 5
L. 1	M. 3	N. 25	O. 10	R. −1	S. 8	T. −2	U. 7	W. $\frac{1}{4}$	Y. 9

10	36	3	27	14	6

19	30	12	26	33	13

15	16	5	18	34	31	2

9	35	20	21	28	17

7	11	23

1

4	25	22	24

29	8	32

Finding Inverses of Logarithmic Functions Using Properties of Logs

(We will be examining how to apply properties of logarithms to find their exponential inverse)

Remember: $y = b^x$ <=> $\log_b y = x$

Example 1: Find the inverse of $y = \log_2 x + 1$

Hint: If $y = b^x$ <=> $\log_b y = x$ and when we find the inverse we swap x and y...

Example 2: Find the inverse of $y = log_4(x+2) - 5$

Example 3: Find the inverse of $y = ln(x+7)$

Adv. Alg. - INVERSES OF EXPONENTIAL/LOG FUNCTIONS Name ____________________

Find the inverse of each of the following functions.

1. $y = 3^x$	2. $y = \log_7 x$
3. $y = \log_2 x + 1$	4. $y = 5^x - 1$
5. $y = 6^{x+3}$	6. $y = \log_{\frac{1}{4}}(x+3)$
7. $y = \log(x-9)$	8. $y = e^{x-2}$
9. $y = 2^{x-4} - 3$	10. $y = \ln x + 5$
11. $y = \log_3(x-2) - 4$	12. $y = 4^{x+1} + 8$

WHAT MATHEMATICAL TOPIC IS DISCUSSED BY THE MUSICIANS IN A GERMAN BEER HOUSE?

Match the letter of each logarithmic equation with the number of the exponential equation.

1) $2^3 = 8$	2) $3^2 = 9$	3) $9^{1/2} = 3$	4) $5^{-1} = \frac{1}{5}$
5) $2^0 = 1$	6) $4^3 = 64$	7) $8^{1/3} = 2$	8) $8^{2/3} = 4$
9) $a^b = x$	10) $b^x = a$	11) $x^a = b$	12) $a^x = b$

Logarithmic Form

A. $\log_8 4 = \frac{2}{3}$	B. $\log_b x = a$	C. $\log_8 \left(\frac{1}{3}\right) = 2$	E. $\log_8 2 = \frac{1}{3}$
G. $\log_9 3 = \frac{1}{2}$	H. $\log_4 64 = 3$	H. $\log_2 1 = 0$	K. $\log_{64} 4 = 3$
L. $\log_2 8 = 3$	M. $\log_x b = a$	R. $\log_a b = x$	R. $\log_5 \left(\frac{1}{5}\right) = -1$
S. $\log_a x = b$	T. $\log_3 9 = 2$	X. $\log_3 2 = 9$	Y. $\log_b a = x$

1	8	3	7	12

4	6	10	2	5	11	9

WHAT TYPE OF DWELLING DOES "X" REPRESENT IN THE EQUATION 10^X = CABN?

Match the letter of each exponential equation with the number of the logarithmic equation.

1) $\log_2 32 = 5$	2) $\log_5 1 = 0$	3) $\log_5 125 = 3$	4) $\log_{\sqrt{2}} 2 = 2$
5) $\log_{64} 8 = \frac{1}{2}$	6) $\log_2 \left(\frac{1}{8}\right) = -3$	7) $\log_{27} 9 = \frac{2}{3}$	8) $\log_3 \left(\frac{1}{3}\right) = -1$

Exponential Form

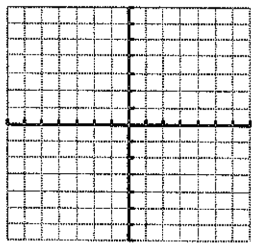
A. $2^{-3} = \frac{1}{8}$	B. $2^5 = 32$	C. $64^{1/2} = 8$	D. $5^2 = 32$
D. $125^3 = 5$	G. $5^3 = 125$	H. $5^1 = 0$	I. $5^0 = 1$
L. $3^{-1} = \frac{1}{3}$	M. $3^{-1} = -3$	N. $27^{2/3} = 9$	O. $(\sqrt{2})^2 = 2$

8	4	3

5	6	1	2	7

Graphing Logarithmic Functions Notes

$f(x) = \log_4 x$



Domain ________

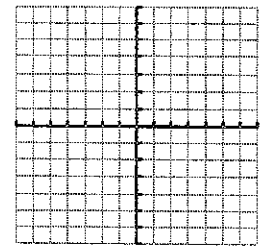
Range ________

Asymptote ________

Equation of the inverse

____

$f(x) = \log_4(x - 3)$



Domain ________

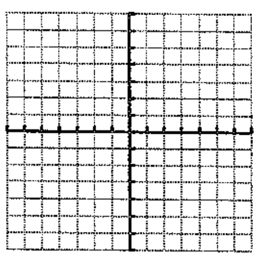
Range ________

Asymptote ________

Equation of the inverse

____

$f(x) = \log_2 x + 4$



Domain ________

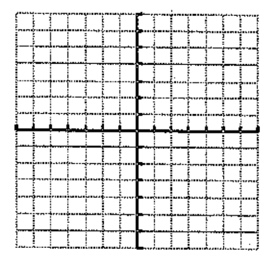
Range ________

Asymptote ________

Equation of the inverse

____

$f(x) = \ln(x + 1) - 2$



Domain ________

Range ________

Asymptote ________

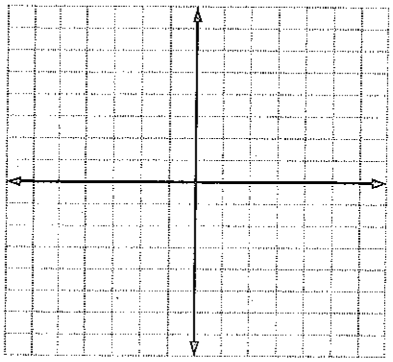
Equation of the inverse

____

Graphing Logs WS 2 Name ______________________

Graph each of the functions. Be sure the asymptote appears on your graph.
Also identify the domain, range, and asymptote.

1. $y = \log_5(x-3)$

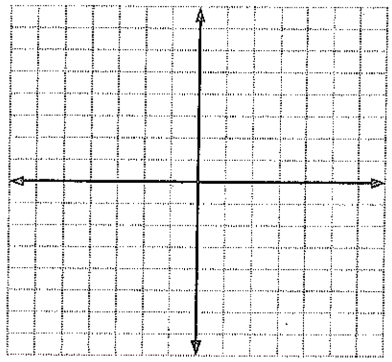


D ______________

R ______________

Asymptote ____________

2. $y = \log_4 x + 4$

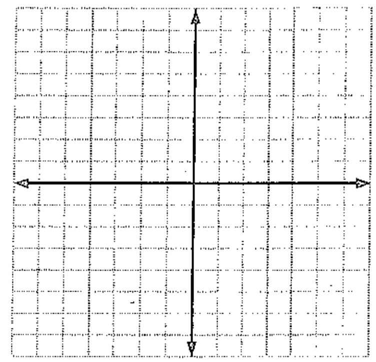


D ______________

R ______________

Asymptote ____________

3. $y = \log_3(x-2)+3$

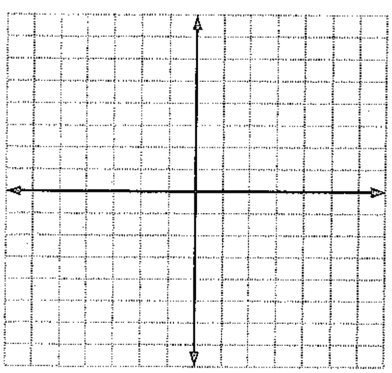


D ______________

R ______________

Asymptote ____________

4. $y = \ln(x+2)$

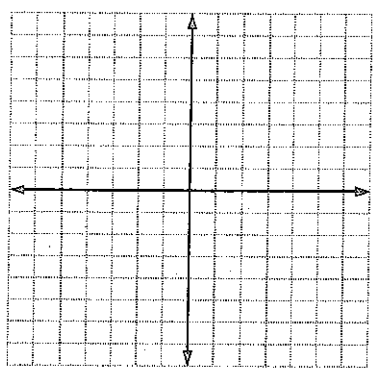


D ______________

R ______________

Asymptote ____________

5. $y = \log_2(x+4)-2$

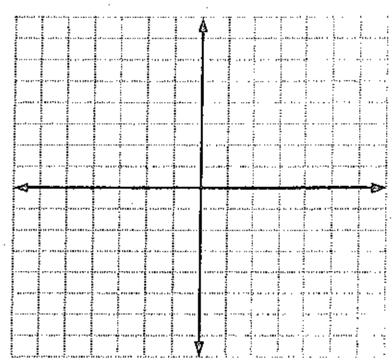


D ______________

R ______________

Asymptote ____________

6. $y = \ln(x-1)+5$



D ______________

R ______________

Asymptote ____________

Properties of Logarithms

Special Logarithm Values

Let b be positive numbers such that $b \neq 1$.

$$\log_b 1 = 0$$

$$\log_b b = 1$$

Inverse Properties

Let b be positive numbers such that $b \neq 1$.

$$\log_b b^n = n$$

$$b^{\log_b n} = n$$

Properties of Logarithms

Let b, u, and v be positive numbers such that $b \neq 1$.

Examples:

Product Property $\log_b uv = \log_b u + \log_b v$

Quotient Property $\log_b \frac{u}{v} = \log_b u - \log_b v$

Power Property $\log_b u^n = n \log_b u$

Example 1:

Use $\log_a \approx 0.732$ and $\log_a 11 \approx 1.091$ to approximate the following.

a. $\log_a \frac{5}{11}$

b. $\log_a 55$

c. $\log_a 25$

Example 2:
Expand each logarithm. Assume x is positive.

a. $\log_2 \frac{x}{2}$

b. $\log_3 9x$

c. $\log_5 2x^6$

Example 3:
Condense each logarithm.

a. $\log_4 2 + \log_4 8$

b. $2\log_3 5 + \frac{1}{2}\log_3 x$

c. $2\log_3 7 - 5\log_3 x$

Log Properties WS Name ______________________________

Use a property of logarithms to evaluate the expression.

1. $\log_3(3 \cdot 9)$
2. $\log_2 4^5$
3. $\log_3 \frac{1}{3}$
4. $\log_5 \left(\frac{1}{5}\right)^3$

Use the change of :e the value of the expression.

SKIP

5. $\log_2 3$
6. $\log_2 49$
7. $\log_2 147$
8. $\log_2 441$

Expand the express.......

9. $\log_2 9x$
10. $\log 4x^5$
11. $\log_4 \frac{4}{3}$
12. $\ln 3xy^3$
13. $\log_8 64x^2$
14. $\log \sqrt{x}$

Condense the expression.

15. $2\log x + \log 5$
16. $4\log_{16} 12 - 4\log_{16} 2$
17. $7\log_4 2 + 5\log_4 x + 3\log_4 y$
18. $10\log x + 2\log 10$
19. $2(\log_6 15 - \log_6 5) + \frac{1}{2}\log_6 \frac{1}{25}$
20. $\frac{1}{4}\log_5 81 - \left(2\log_5 6 - \frac{1}{2}\log_5 4\right)$

MATH 3 NAME ____________________

LOG PROPERTIES—EXPANDING AND CONDENSING

1- 9 Expand each of the following using the properties of logs.

1. $\log_3 6x$	2. $\log_6 x^5$	3. $\log_5 \frac{7}{3}$
4. $\log 5x^4 y^2$	5. $\log_3 \sqrt{x}$	6. $\ln \frac{2}{xy}$
7. $\log \frac{3y^4}{4x^{\frac{1}{3}}}$	8. $\log_3 \sqrt{5p}$	9. $\log_4 \frac{9(x+1)}{(x+2)}$

#10-18. Condense the following using the properties of logs.

10. $\log_2 3 + \log_2 x$	11. $\log_5 8 - \log_5 3$	12. $5\log_7 r$
13. $2\ln 3 - \ln 5$	14. $\log 20 + 2\log y + \log z$	15. $\log_3 2 + \frac{1}{2}\log_3 y$
16. $\log_2 x + \log_2 y - \log_2 3$	17. $\log_4 (x+1) - \log_4 7 - 2\log_4 y$	18. $\ln 5 - \ln 3 - \ln x - \ln y$

Solving Log Equations

Using Log Properties

1. Solve and check.

$\log_4(x+3) = 2$

2. Solve and check.

$\log_4(x+3) = \log_4(8x+17)$

3. Solve and check.

$\log_2 x + \log_2(x-7) = \log_2 8$

4. Solve and check.

$$\log(2x+3) = 1 + \log(x-3)$$

Math 3 Solving with
Properties of Logarithms

Name ______________________________

I. Evaluate each expression

1. $n^{\log_n 3}$	2. $14^{\log_{14} 6}$

II. Use $\log_{10} 5 = 0.6990$ and $\log_{10} 7 = 0.8451$ to evaluate each expression.

3. $\log_{10} 35$	4. $\log_{10} \frac{7}{5}$
5. $\log_{10} 25$	6. $\log_{10} 490$
7. $\log_{10}\left(1\frac{3}{7}\right)$	8. $\log_{10} 0.05$

III. Solve each equation.

9. $\log_6 x + \log_6 9 = \log_6 54$	10. $\log_8 48 - \log_8 w = \log_8 4$
11. $\log_7 n = \frac{2}{3}\log_7 8$	12. $\log_3 y = \frac{1}{4}\log_3 16 + \frac{1}{3}\log_3 64$
13. $\log_9(3u+14) - \log_9 5 = \log_9 2u$	14. $\log_7 x + \log_7 x = \log_7 12$
15. $4\log_2 x + \log_2 5 = \log_2 405$	16. $\log_6(2x-5) + 1 = \log_6(7x+10)$
17. $\log_{16}(9x+5) - \log_{16}(x^2-1) = \frac{1}{2}$	18. $\log_8(n-3) + \log_8(n+4) = 1$

Math 3 Name ______________________________

Log Functions and Log Equations

I. Expand each logarithmic expression

1. $\log_2 2x^2y^3$	2. $\log_5 \frac{10x}{y^2}$

II. Condense each logarithmic expression

3. $\log_3 x+\log_3 y-3\log_3 z$	4. $3\log_4 2-(2\log_4 x+\log_4 y)$

III. Solve each equation.

4. $\log_4 x=\frac{3}{2}$	5. $\log_y 16=-4$
6. $\log_a \frac{1}{8}=-3$	7. $\log_7 n=-\frac{1}{2}$
8. $\log_{\sqrt{5}} y=\frac{4}{3}$	9. $\log_x \sqrt[3]{9}=\frac{1}{6}$
10. $\log_8(3x+7)=\log_8(7x+4)$	11. $\log_7(8x+20)=\log_7(x+6)$
12. $\log_3(9x-1)=\log_3(4x-16)$	13. $\log_{12}(x-9)=\log_{12}(3x-13)$
14. $\log_5(x^2-30)=\log_5 6$	15. $\log_4(x^2+6)=\log_4 5x$
16. $\log x+\log 6=1$	17. $\log_2 x=\frac{1}{2}\log_2 81$
18. $\log_3 14+\log_3 x=\log_3 42$	19. $\log_4(y-1)=\log_4(y-1)=2$
20. $\log_4(1-2x)=\log_4(x+10)$	21. $\log_7(m+1)+\log_7(m-5)=1$
22. $\log_5 7+\frac{1}{2}\log_5 4=\log_5 x$	23. $\log_8(y+1)-\log_8 y=\log_8 4$
24. $\log_6(x-3)+\log_6(x+2)=2$	

SOLVING EXPONENTIAL EQUATIONS ...

... with un-like bases

1. Solve: $5^x = 25$

2. Solve: $3^x = 25$

3. Solve: $e^x = 26$

4. Solve: $2(3)^{2t-5} - 4 = 11$

5. Solve: $e^{2x} - 3e^{x} + 2 = 0$

6. Solve: $5^x = 7^{x-1}$

Math 3

Exponential Equations with Mixed Bases

Name ______________________________

Solve each equation. Round your answer to three decimal places.

1. $13^x = 7$	2. $4^{5x} = 9$
3. $6^{x+2} + 1 = 3$	4. $1.5 = 2.7^{2x-3} - 4$
4. $5^{-4x} = 3.21$	5. $8^{\frac{x}{5}} = 3$
7. $4^{2x} = 9^{x-1}$	8. $7^{3x} = 12^{x+2}$

9. $e^x = 5.1$	10. $e^{x-4} + 1 = 5$
11. $5e^{-7x} = 23$	12. $200e^{x+5} - 3 = 60$

ANSWERS: 1. .759 2. .317 3. -1.613 4. 2.358 5. -.181 6. 2.642
6. -3.819 8. 1.482 9. 1.629 10. 5.386 11. -.218 12. -6.155

Exp and Log Equations WS   Name ______________________

Solve the equation.

1. $10^{x-3} = 100^{4x-5}$

2. $3^{x-7} = 27^{2x}$

3. $8^{5x} = 16^{3x+4}$

4. $e^{-x} = 6$

5. $.25^{x} - .5 = 2$

6. $7^{2x} + 3 = 8$

7. $10^{-12x} + 6 = 100$

8. $-16 + 0.2(3)^{x} = 35$

Solve the equation. Check for extraneous solutions.

9. $\ln(4x+1) = \ln(2x+5)$

10. $\log_2 x = -1$

11. $4\log_3 x = 28$

12. $1 - 2\ln x = -4$

13. $\ln x + \ln(x-2) = 1$

14. $\log_8(11-6x) = \log_8(1-x)$

15. $15 + 2\log_2 x = 31$

16. $6.5\log_5 3x = 20$

Answers: 1) 1 2) –7/5 3) 16/3 4) –1.79 5) –0.66 6) 0.41 7) –0.164 8) 5.04
9) 2 10) ½ 11) 2187 12) 12.18 13) $1+\sqrt{1+e}$ 14) $\varnothing$ 15) 256 16) 47.16

Change-of-Base Formula

Change of Base Formula

Let u, b, and c be positive numbers with $b \neq 1$ and $c \neq 1$. Then:

$$\log_c u = \frac{\log u}{\log c} \quad \text{and} \quad \log_c u = \frac{\ln u}{\ln c}$$

Evaluate each using common and natural logarithms.

a. $\log_2 8$ b. $\log_4 8$ c. $\log_3 25$

Change-of-Base WS 1

Name ______________________________

Use a calculator to approximate each to the nearest thousandth.

1) $\log_3 3.3$

2) $\log_2 30$

3) $\log_4 5$

4) $\log_2 2.1$

5) $\log_{3.5} 5$

6) $\log_6 13$

7) $\log_6 40$

8) $\log 43.5$

9) $\log_2 2.9$

10) $\log_6 22$

11) $\log_7 8.7$

12) $\log_3 62$

Student Name: ____________________ **Score:**

Rewrite as Single Logarithm Using Change of Base Rule

$Example: \dfrac{\log_5 8}{\log_5 3} = \log_3 8$

$\dfrac{\log_2 15}{\log_2 6} =$ ____________

$\dfrac{\log_4 9}{\log_4 5} =$ ____________

$\dfrac{\log_3 8}{\log_3 7} =$ ____________

$\dfrac{\log_{10} 5}{\log_{10} 2} =$ ____________

$\dfrac{\log_{11} 6}{\log_{11} 2} =$ ____________

$\dfrac{\log_3 10}{\log_3 5} =$ ____________

Doubling-Time & Half-Life

1 Exponential Growth & Decay

Recall the formula we developed for compound interest,

$$A = P\left(1 + \frac{r}{n}\right)^{nt},$$

where

$$\begin{aligned} A &= \text{accumulated amount of investment,} \\ P &= \text{initial investment,} \\ r &= \text{annual interest rate,} \\ n &= \text{number of compoundings per year,} \\ t &= \text{number of years.} \end{aligned}$$

We can rewrite the above formula in words as:

$$\left(\begin{array}{c}\text{Accumulated}\\ \text{Amount}\end{array}\right) = \left(\begin{array}{c}\text{Initial}\\ \text{Amount}\end{array}\right)\left[1 + \left(\begin{array}{c}\text{Rate of Growth}\\ \text{Per Period}\end{array}\right)\right]^{\text{(Number of Periods)}}.$$

The benefit of writing the formula in words is that we can now see our "monetary terms" from the compound interest formula have disappeared, so there is no reason the formula can't be applied to other types of problems involving amounts growing (or decaying – i.e., decreasing in amount). We now discuss Doubling-Time and Half-Life, which are two examples of how this formula can be applied to non-investment type problems.

2 Doubling-Time

Consider the following motivational problem:

> **Problem 1** – Small rural water systems are often contaminated with bacteria by animals. Suppose that a water tank is infested with a colony of 100,000 *E. coli* bacteria. In this tank the colony doubles in number every 4 days. Determine a formula, $A(t)$, for the number of bacteria present in the tank after t days.

We will proceed by using our formula,

$$\left(\begin{array}{c}\text{Accumulated}\\ \text{Amount}\end{array}\right) = \left(\begin{array}{c}\text{Initial}\\ \text{Amount}\end{array}\right)\left[1 + \left(\begin{array}{c}\text{Rate of Growth}\\ \text{Per Period}\end{array}\right)\right]^{\text{(Number of Periods)}}.$$

The amount of time it takes the bacteria to double is 4 days, so this is our **period**. Since the bacteria doubles every 4 days, the amount of bacteria increases by 100% every 4 days (or each period). Hence, the **rate of growth per period** is 1.00 (corresponding to the 100% increase). The **number of periods** that have passed after t days is given by $\frac{t}{4}$ (since our period is 4 days). Therefore, starting with an **initial amount** of 100,000 our formula becomes

$$\begin{aligned} A(t) &= (100,000)[1 + 1.00]^{\frac{t}{4}} \\ &= 100,000(2)^{\frac{t}{4}}. \end{aligned}$$

Log Word Problems WS Name ____________________

Use the following formulas:

- Exponential Growth: $y = a(1+r)^t$
- Exponential Decay: $y = a(1-r)^t$
- Continuously Compounded Interest: $A = Pe^{rt}$

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1. You buy a commemorative coin for $110. Each year t, the value V of the coin increases by 4%. How long will it take for the value of the coin to reach $200?

2. You deposit $1600 in a bank account. How long will it take for the value of the account to reach $2,000 if the account pays 4% annual interest compounded yearly.

3. You purchased a plot of land that for $45,000. The value of the land increases by approximately 5% each year. How long will it take for the value of the land to double?

4. You buy a new car for $22,000. The value of the car decreases by 12.5% each year. When will the car have a value of $10,000?

5. You buy a stereo system for $780. Each year the value of the stereo system decreases by 5%. When it was destroyed in a flood, your insurance only paid the depreciated value of $250. How long did you own the stereo before the flood?

6. You deposit $975 in an account that compounds interest continuously. After 5 years, the value of the account is $1132.79. What percent interest was the account paying?

Answers: 1) 15.26 years 2) 5.7 years 3) 14.2 years 4) 5.9 years 5) 22 years 6) 3%

Assorted Log Word Problems WS 2 Name____________________

1. The exponential growth model $P = 5344e^{0.012744t}$ approximates the world population (in millions) from 1990. According to this model, when will the world population reach 68 million?

2. The number N of bacteria in a culture is given by the model $N = 100e^{0.2197t}$ where t is the time in hours. Estimate the time required for the population to double in size?

3. A satellite has a radioisotope power supply. The power output in watts is given by the equation $P = 50e^{\frac{-t}{250}}$, where t is the time in days since the power supply was placed in service.
   a) How much power will be available at the end of one year?
   b) The equipment aboard the satellite requires 10 watts of power to operate properly. What is the operational life of the satellite?

4. You buy a commemorative coin for $110. Each year t, the value V of the coin increases by 4%. In how many years will the coin be worth $250?

5. Suppose $500 is invested at 6% annual interest compounded continuously. When will the investment be worth $1000?

6. An investment service promises to triple your money in 12 years. Assuming continuous compounding of interest, what rate of interest is needed?

7. A piece of machinery valued at $250,000 depreciates at 12% per year by the fixed rate method. After how many years will the value have depreciated to $100,000?

Answers: 1) t = 18.9 → 2009 2) 3.15 hours 3a) 11.61 watts 3b) 402 days

4) 21 years 5) 11.6 years 6) 9.16% 7) 7.17 years