**Unit Goals – Stage 1**

- **Number of Days:** 33 days
1/30/17 – 3/17/17

**Unit Description:** In Unit 4, students add to their list of function families with exponential and logarithmic functions. Drawing on their experience with exponential growth and decay functions in Algebra 1, students will be working with the natural base, $e$, along with other bases, and applying them to compound interest, continuous compounding, and other applications. Logarithmic functions follow naturally from an exploration of the properties of exponents. Graphs confirm the inverse relationship between exponential and logarithmic functions. Transformations of the graphs of these functions reinforce that transformations on a graph always have the same effect regardless of the type of underlying function. Exponential functions lead naturally to geometric sequences. New this year is the skill of adding the terms of a sequence. Along with arithmetic and geometric sequences and series, partial sums and sums of infinite geometric series will be explored numerically and graphically.

**Materials:** Graphing calculators, Desmos

<table>
<thead>
<tr>
<th>Standards for Mathematical Practice</th>
<th>Transfer Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SMP 1</strong> Make sense of problems and persevere in solving them.</td>
<td><strong>Students will be able to independently use their learning to...</strong></td>
</tr>
<tr>
<td><strong>SMP 2</strong> Reason abstractly and quantitatively.</td>
<td><strong>• Make sense of never-before-seen problems and persevere in solving them.</strong></td>
</tr>
<tr>
<td><strong>SMP 3</strong> Construct viable arguments and critique the reasoning of others.</td>
<td><strong>• Construct viable arguments and critique the reasoning of others.</strong></td>
</tr>
<tr>
<td><strong>SMP 4</strong> Model with mathematics.</td>
<td><strong>Making Meaning</strong></td>
</tr>
<tr>
<td><strong>SMP 5</strong> Use appropriate tools strategically.</td>
<td><strong>UNDERSTANDINGS</strong></td>
</tr>
<tr>
<td><strong>SMP 6</strong> Look for and make use of structure.</td>
<td><strong>Students will understand that...</strong></td>
</tr>
<tr>
<td><strong>SMP 7</strong> Look for and express regularity in repeated reasoning.</td>
<td><strong>• Each step in solving a simple equation follows from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution.</strong></td>
</tr>
</tbody>
</table>

**Standards for Mathematical Content Clusters Addressed**

[m] A-SSE.A Interpret the structure of expressions.

**ESSENTIAL QUESTIONS**

**Students will keep considering...**

- Where do you see exponential growth and decay in the real-world?
- Why can $b$ never equal 0 or 1?
- What is the effect on an exponential or logarithmic graph when you replace $f(x)$ with $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x + k)$?
- How do you know that two functions are inverses of each other?
- In a real-world context, what purpose is served by an asymptote?
- Where do you see logarithmic models in the real-world?
- Why are there different bases for exponential and logarithmic equations?
- How are exponents and logarithms related?
- How are the graphs of exponential and logarithmic functions related?
- How can you determine if a real-world situation should be represented by a quadratic, polynomial, exponential, or logarithmic function?
- What IS a logarithm?
### Unit Goals – Stage 1

<table>
<thead>
<tr>
<th><strong>KNOWLEDGE</strong></th>
<th><strong>SKILLS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students will know...</strong></td>
<td><strong>Students will be skilled at and/or be able to...</strong></td>
</tr>
<tr>
<td>- Exponential functions have a constant as the base and a variable in the exponential position.</td>
<td>- Use the structure of an expression to identify ways to rewrite it.</td>
</tr>
<tr>
<td>- Given an exponential function, ( y = ab^{cx} ), ( b ) can be greater than 1 (growth) or between 0 and 1 (decay). ( B ) cannot equal 1 or be less than or equal to 0.</td>
<td>- Use the properties of exponents to transform expressions for exponential functions.</td>
</tr>
<tr>
<td>- Exponential functions and logarithmic functions are “bound” by asymptotes.</td>
<td>- Create equations in two or more variables to represent relationships between quantities.</td>
</tr>
<tr>
<td>- The effect on the graph of each of the parameters in the equation ( y = ab^{x} + h ).</td>
<td>- Graph equations on coordinate axes with labels and scales.</td>
</tr>
<tr>
<td>- When to use ( e ) as a base.</td>
<td>- Graph exponential and logarithmic functions, showing intercepts, asymptotes and end behavior.</td>
</tr>
<tr>
<td>- Logarithms and exponential functions are inverses.</td>
<td>- Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.</td>
</tr>
<tr>
<td>- The effect on the graph of each of the parameters in the equation ( y = \log_{b}(x-k) + h ).</td>
<td>- Use the properties of exponents to interpret expressions for exponential functions.</td>
</tr>
<tr>
<td>- The Properties of Logarithms.</td>
<td>- Write an exponential or logarithmic function that describes a relationship between two quantities.</td>
</tr>
<tr>
<td>- The Change of Base Formula.</td>
<td>- Identify the effect on the graph when ( f(x) ) is replaced by ( f(x) + k, k f(x), f(kx), ) or ( f(x + k) ) for specific values of ( k ) both positive and negative; find the value of ( k ) given the graph.</td>
</tr>
<tr>
<td>- Sequence and series notation.</td>
<td>- Solve an equation of the form ( f(x) = c ) for a simple function ( f ) that has an inverse, and write an expression for the inverse.</td>
</tr>
<tr>
<td></td>
<td>- Construct exponential functions, including geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table) and justify that function.</td>
</tr>
<tr>
<td></td>
<td>- For exponential models, express as a logarithm the solution to ( ab^{cx} = d ) where ( a, c, ) and ( d ) are numbers and the base ( b ) is 2, 10, or ( e ); evaluate the logarithm using technology.</td>
</tr>
<tr>
<td></td>
<td>- Prove simple laws of logarithms.</td>
</tr>
<tr>
<td></td>
<td>- Use the definition of logarithms to translate between logarithms in any base.</td>
</tr>
<tr>
<td></td>
<td>- Understand and use the properties of logarithms to simplify logarithmic numeric expressions and to identify their approximate values.</td>
</tr>
<tr>
<td></td>
<td>- Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems.</td>
</tr>
<tr>
<td></td>
<td>- Use proper notation to write rules for arithmetic and geometric sequences both recursively and with an explicit formula, and use the rules to model situations.</td>
</tr>
<tr>
<td></td>
<td>- Translate between recursive and explicit rules for sequences.</td>
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<tr>
<td></td>
<td>- Find sums of finite arithmetic and geometric series and partial sums of infinite geometric series.</td>
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<tr>
<td></td>
<td>- Use explicit and recursive rules to solve real-world problems.</td>
</tr>
</tbody>
</table>
Assessed Grade Level Standards

**Standards for Mathematical Practice**

SMP 1  Make sense of problems and persevere in solving them.
SMP 2  Reason abstractly and quantitatively.
SMP 3  Construct viable arguments and critique the reasoning of others.
SMP 4  Model with mathematics.
SMP 5  Use appropriate tools strategically.
SMP 6  Attend to precision.
SMP 7  Look for and make use of structure.
SMP 8  Look for and express regularity in repeated reasoning.

**Standards for Mathematical Content**

[m] A-SSE.A  Interpret the structure of expressions.
A-SSE.2  Use the structure of an expression to identify ways to rewrite it. For example, see $x^4 - y^4$ as $(x^2 + y^2)(x^2 - y^2)$, thus recognizing it as a difference of squares that can be factored as $(x^2 - y^2)(x^2 + y^2)$.

[m] A-SSE.B  Write expressions in equivalent forms to solve problems.
A-SSE.3  Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.
c. Use the properties of exponents to transform expressions for exponential functions. For example the expression $1.15t$ can be rewritten as $1.15^{1/12}12t \approx 1.012^{12t}$ to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.
A-SSE.4  Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems. For example, calculate mortgage payments.

[m] A-CED.A  Create equations that describe numbers or relationships.
A-CED.2  Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

[m] A-REI.A  Understand solving equations as a process of reasoning and explain the reasoning.
A-REI.1  Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

[s] F-IF.C  Analyze functions using different representations.
F-IF.7  Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.
F-IF.8  Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.
b. Use the properties of exponents to interpret expressions for exponential functions. For example, identify percent rate of change in functions such as $y = (1.02)^t$, $y = (0.97)^t$, $y = (1.01)^{12t}$, $y = (1.2)^{10t}$, and classify them as representing exponential growth or decay.

[m] F-BF.A  Build a function that models a relationship between two quantities.
### Assessed Grade Level Standards

<table>
<thead>
<tr>
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</table>
| **F-BF.1** | Write a function that describes a relationship between two quantities.  
  a. Determine an explicit expression, a recursive process, or steps for calculation from a context. |
| **F-BF.2** | Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms. |
| **F-BF.3** | Build new functions from existing functions.  
  a. Identify the effect on the graph of replacing \( f(x) \) by \( f(x) + k, k f(x), f(kx), \) and \( f(x + k) \) for specific values of \( k \) (both positive and negative); find the value of \( k \) given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology.  
  *Include recognizing even and odd functions from their graphs and algebraic expressions for them.*  
  b. Find inverse functions.  
  a. Solve an equation of the form \( f(x) = c \) for a simple function \( f \) that has an inverse and write an expression for the inverse. For example, \( f(x) = 2x^3 \) or \( f(x) = (x+1)/(x-1) \) for \( x \neq 1 \). |
| **F-L.E.A** | Construct and compare linear, quadratic, and exponential models and solve problems.  
  a. Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).  
  b. For exponential models, express as a logarithm the solution to \( ab^{ct} = d \) where \( a, c, \) and \( d \) are numbers and the base \( b \) is 2, 10, or \( e \); evaluate the logarithm using technology.  
  c. Prove simple laws of logarithms. CA  
  d. Use the definition of logarithms to translate between logarithms in any base. CA  
  e. Understand and use the properties of logarithms to simplify logarithmic numeric expressions and to identify their approximate values. CA |

**Key:**
- [m] = major clusters; [s] = supporting clusters, [a] = additional clusters
- * Indicates a modeling standard linking mathematics to everyday life, work, and decision-making
- CA Indicates a California-only standard
## Evidence of Learning – Stage 2

### Assessment Evidence

**Unit Assessment**

**Claim 1:** Students can explain and apply mathematical concepts and carry out mathematical procedures with precision and fluency.

Concepts and skills that may be assessed in Claim 1:

- **A-SSE.A**
  - Use the structure of an expression to identify ways to rewrite it.

- **A-SSE.B**
  - Choose and produce an equivalent form of an expression to reveal and explain the properties of the quantity represented by the expression.
  - Use the properties of exponents to transform expressions for exponential functions.
  - Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems.

- **A-CED.A**
  - Create equations in two variables to represent relationships between quantities.
  - Graph equations on coordinate axes with labels and scales.

- **A-REI.A**
  - Explain each step in solving an equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution.
  - Construct a viable argument to justify a solution method.

- **F-IF.C**
  - Graph exponential and logarithmic functions, showing intercepts, asymptotes and end behavior.
  - Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.
  - Use the properties of exponents to interpret expressions for exponential functions.

- **F-BF.A**
  - Write a function that describes a relationship between two quantities.
  - Write arithmetic and geometric sequences both recursively and with an explicit formula, and use them to model situations.
  - Translate between explicit and recursive forms.

- **F-BF.B**
  - Identify the effect on the graph when \( f(x) \) is replaced by \( f(x) + k, k f(x), f(kx), \) or \( f(x + k) \) for specific values of \( k \) both positive and negative; find the value of \( k \) given the graph.
  - Find inverse functions.
  - Solve an equation of the form \( f(x) = c \) for a simple function \( f \) that has an inverse, and write an expression for the inverse.
### Evidence of Learning – Stage 2

| F-LE.A | • Construct exponential functions, including geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
• For exponential models, express as a logarithm the solution to \( ab^{cd} = d \) where \( a, c, \) and \( d \) are numbers and the base \( b \) is 2, 10, or \( e \).
• Evaluate logarithms using technology.
• Prove simple laws of logarithms.
• Use the definition of logarithms to translate between logarithms in any base.
• Understand and use the properties of logarithms to simplify logarithmic numeric expressions and to identify their approximate values. |

**Claim 2:** Students can solve a range of well-posed problems in pure and applied mathematics, making productive use of knowledge and problem-solving strategies.
Standard clusters that may be assessed in Claim 2:
• A-SSE.A
• A-SSE.B
• A-CED.A
• A-REI.A
• F-IF.C
• F-BF.A

**Claim 3:** The student can clearly and precisely construct viable arguments to support their own reasoning and critique the reasoning of others.
Standard clusters that may be assessed in Claim 3:
• A-SSE.A
• A-REI.A
• F-IF.C
• F-BF.B

**Claim 4:** The student can analyze complex, real-world scenarios and can construct and use mathematical models to interpret and solve problems.
Standard clusters that may be assessed in Claim 4:
• A-SSE.B
• A-CED.A
• A-REI.A
• F-IF.C
• F-BF.A
• F-LE.A

### Other Evidence

**Formative Assessment Opportunities**

- Opening Tasks
- Informal teacher observations
- Checking for understanding using active participation strategies
- Exit slips/Summaries
- Modeling Lessons (SMP 4)
- Tasks
- Formative Assessment Lessons (FAL)
- Quizzes/Chapter Tests
- Big Ideas Math Performance Tasks
- SBAC Interim Assessment Blocks

# Unit 4 Exponential and Logarithmic Functions

## Learning Plan – Stage 3

### Suggested Sequence of Key Learning Events and Instruction

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<th>Learning Target</th>
<th>Expectations</th>
<th>Big Ideas Math Algebra 2 (Activities and Lessons)</th>
<th>Curriculum Intranet</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>OPENING TASK – Zombie Alert</td>
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<td></td>
</tr>
<tr>
<td>1 day</td>
<td>I will use my knowledge of exponential and logarithmic equations to solve a real-world application in the Opening Task.</td>
<td>The purpose of this Opening Task is to motivate your students to want to learn logarithms. Using their knowledge from Algebra 1, they will create a simple exponential function based on the given data in which time is the unknown. The goal is to find out how long it will take the entire given student body to turn into zombies. Students have never seen logarithms before. They will approach the solution using guess and check. After they have their best answer, have them put their work away. They will be able to solve the problem precisely in a few days. A suggestion would be for you to change the problem so that it refers to your school and your student body.</td>
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</tr>
</tbody>
</table>
| 2 - 4 days | I will show an understanding of exponential functions by… | - Solving exponential growth and decay applications including compound interest.  
- Determining whether an exponential function is growth or decay and identifying the growth/decay factor.  
- Graphing an exponential function, by hand or using technology, and identifying its intercepts, end behavior and asymptotes. Discuss those characteristics in the context of the problem.  
- Using the context of the problem, interpret the values of the parameters in \( y=ab^{x+k}+h \).  
- Finding the value of \( e \).  
- Answering questions such as:  
  o What are some of the characteristics of an exponential function? Graph?  
  o Why can the base of an exponential function never be 0 or 1?  
  o Why, if \( 0 < b < 1 \), is there exponential decay? | - Lesson 6.1  
- Lesson 6.2 | Procedural Skills and Fluency:  
- Simple and Compound Interest Problems  
- Compounded Continuously Problems  
- Desmos: Marbleslides Exponentials  
Application:  
- Exponential Decay: Counting M&M’s  
- Three-Act Lesson: Pixel Pattern  
- Home Mortgage Project |
<table>
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</thead>
</table>
| 2 - 4 days | I will show an understanding of logarithms by… | • Using the properties of exponents to simplify an exponential expression.  
• Using the properties of exponents to define logarithms.  
• Writing exponents as logarithms and logarithms as exponents.  
• Using the inverse properties of logarithmic and exponential functions.  
• Graphing logarithmic functions by hand and using technology.  
• Describing a transformation when given a function.  
• Writing a function when given a description of a transformed graph.  
• Answering questions such as:  
  o What are some of the characteristics of an logarithmic function? Graph?  
  o How can you use the graph of an exponential function to find the graph of a logarithmic function?  
  o What is the domain of $y=\log_bx$? Range? Always?  
  o The graph of $f(x)$ can be effected by $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x + k)$. Can you generalize from other types of functions what effect $k$ has on a parent graph? | • Lesson 6.3  
• Lesson 6.4 | Conceptual Understanding:  
• Falling off a Log: Graphing  
• Graphing Exponential and Logarithmic Functions  
• Illustrative Mathematics: Exponentials and Logarithms 1  
• Which One Doesn’t Belong: Log Graphs  
Procedural Skills and Fluency:  
• Matching Inverse Functions: Inverse Universe  
• Desmos: Polygraph Exponential and Logarithmic Functions |
## Learning Plan – Stage 3

### Suggested Sequence of Key Learning Events and Instruction

<table>
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<tr>
<th>Days</th>
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<th>Curriculum Intranet</th>
</tr>
</thead>
</table>
| 2-3 days | I will check my ability to use exponential functions to solve real world problems by participating in the FAL. | **FORMATIVE ASSESSMENT LESSON**  
- Connecting the properties of logarithms with the properties of exponents.  
- Deriving the properties of exponents.  
- Using technology to evaluate a logarithmic expression.  
- Evaluating, expanding and condensing logarithmic expressions.  
- Using the arithmetic properties of equality to solve exponential and logarithmic equations.  
- Using the properties of logarithms to solve logarithmic and exponential equations.  
- Solving exponential and logarithmic inequalities.  
- Recognizing whether a data set is linear, quadratic, polynomial, exponential or logarithmic.  
- Writing an exponential equation when given two points that are on the curve of an exponential function.  
- Fitting a function to a data set with technology.  
- Answering questions such as:  
  - Sometimes, always or never:  
    - \( \log_b(M + N) = \log_b M + \log_b N \) \( (b \neq 1) \)?  
  - How can you use the graph of an exponential function to find the graph of a logarithmic function?  
  - What are various ways we can solve exponential and logarithmic equations?  
  - Compare and contrast exponential and logarithmic functions and graphs. |  
- Lesson 6.5  
- Lesson 6.6  
- STEM Video: Food Safety Regulations  
- Lesson 6.7 | Conceptual Understanding:  
FAL: Representing Linear and Exponential Growth |
| 4-7 days | I will solve real-world problems using exponential and logarithmic functions by... | |  
- Connecting the properties of logarithms with the properties of exponents.  
- Deriving the properties of exponents.  
- Using technology to evaluate a logarithmic expression.  
- Evaluating, expanding and condensing logarithmic expressions.  
- Using the arithmetic properties of equality to solve exponential and logarithmic equations.  
- Using the properties of logarithms to solve logarithmic and exponential equations.  
- Solving exponential and logarithmic inequalities.  
- Recognizing whether a data set is linear, quadratic, polynomial, exponential or logarithmic.  
- Writing an exponential equation when given two points that are on the curve of an exponential function.  
- Fitting a function to a data set with technology.  
- Answering questions such as:  
  - Sometimes, always or never:  
    - \( \log_b(M + N) = \log_b M + \log_b N \) \( (b \neq 1) \)?  
  - How can you use the graph of an exponential function to find the graph of a logarithmic function?  
  - What are various ways we can solve exponential and logarithmic equations?  
  - Compare and contrast exponential and logarithmic functions and graphs. |  
- Lesson 6.5  
- Lesson 6.6  
- STEM Video: Food Safety Regulations  
- Lesson 6.7 | Conceptual Understanding:  
- Chopping Logs: Properties and Transformations  
- Investigating the Properties of Logarithms Task  
Procedural Skills and Fluency:  
- Powerful Tens Review  
- Log-Arithm-Etic Properties Practice  
- Properties of Logarithms: Mix-Freeze-Match  
Application:  
- Flipping Ferraris Task  
- Home Mortgage Project  
- Exponential Growth or Decay Project  
- STEM Performance Task: Preparing a Picnic |
# Unit 4 Exponential and Logarithmic Functions

## Learning Plan – Stage 3

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</table>
| 3-5 days  | I will analyze geometric and algebraic sequences and series by…                  | • Using sequence notation to write the terms of sequences.  
• Writing a rule for the $n^{th}$ term of a sequence.  
• Summing the terms of a sequence to obtain a series and use summation notation.  
• Identify arithmetic and geometric sequences.  
• Writing rules for arithmetic and geometric sequences.  
• Finding sums for finite arithmetic and geometric series.  
• Answering questions such as:  
  o How can you solve for a given term in a sequence?  
  o How can you use the pattern or structure of a sequence to write a rule for that sequence or determine its sum?  
  o Describe and compare the graphs of arithmetic and geometric sequences.  
  o If you double each term in an arithmetic sequence, how will the common difference change?  
  o What are the domains and ranges of arithmetic and geometric sequences?  
  o Sometimes, always or never: The sum formula for a geometric series is only true when $r > 1$. | • Lesson 8.1  
• Lesson 8.2  
• Lesson 8.3 | Conceptual Understanding:  
• Open Middle: Arithmetic vs. Geometric  
Application:  
• Illustrative Mathematics: YouTube Explosion  
• Illustrative Mathematics: Course of Antibiotics  
• Three-Act Lesson: Fry’s Bank Account  
• Three-Act Lesson: Super Stairs |
| 2-5 days  | I will find infinite geometric sums and recursive formulas by…                   | • Finding partial sums of infinite geometric series.  
• Finding sums of infinite geometric series.  
• Writing and evaluating recursive rules for sequences.  
• Translating between recursive and explicit rules for sequences.  
• Using recursive rules to solve real-life problems.  
• Answering questions such as:  
  o As you walk to the door of your classroom, each time you only walk halfway to the door. Will you ever leave your classroom?  
  o How can an infinite series have a finite sum?  
  o Compare an infinite sum when $r > 1$ and when $r < 1$. | • Lesson 8.4  
• Lesson 8.5  
• STEM Video: LA River Ecology | Conceptual Understanding:  
• Recursive and Exponential Rules Activity  
Application:  
• Illustrative Mathematics: Snake on a Plane  
• STEM Performance Task: Wildlife Conservation |
### Learning Plan – Stage 3

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<td></td>
<td></td>
<td>• What role does an asymptote play when summing an infinite geometric series where $0 &lt; r &lt; 1$?</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>• How are explicit and recursive rules different? When would using one, over the other, be advantageous?</td>
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<tr>
<td></td>
<td></td>
<td>• Can you write a recursive rule for a sequence that is neither arithmetic nor geometric?</td>
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</tr>
<tr>
<td>1-2 days</td>
<td>I will prepare for the unit assessment on exponential and logarithmic functions by...</td>
<td>• Incorporating the Standards for Mathematical Practice (SMPs) along with the content standards to review the unit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2 days</td>
<td></td>
<td><strong>Unit Assessment</strong> (LBUSD Math Intranet, Assessment)</td>
<td></td>
<td></td>
</tr>
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