## Big Idea/Topic

- Use function notation to analyze, graph, interpret, and compare linear, exponential, and quadratic functions

## Standard(s) Alignment

- **MGSE9-12.F.IF.7e** Graph exponential functions, showing intercepts and end behavior.
- **MGSE9-12.F.LE.5** Interpret the parameters in a linear \( f(x) = mx + b \) and exponential \( f(x) = a \cdot dx \) function in terms of context. (In the functions above, “m” and “b” are the parameters of the linear function, and “a” and “d” are the parameters of the exponential function.) In context, students should describe what these parameters mean in terms of change and starting value.

## Diagnostic Assessment

### Would You Rather?

Pose students with the following question: “Would you rather have One Million dollars now OR one penny with its value doubled for 30 days? For example, one penny today, two pennies tomorrow, four pennies the next day, and so on.”

Teachers might conduct a poll using a program such as PollEverywhere. Have students respond to the poll by selecting one of the two options.

Provide students the opportunity to investigate the question more deeply. They might benefit from exploring the concept of doubling in this Desmos activity.

Provide students the chance to vote again before the big reveal, explained in this video: Would you take one million dollars now or one coin multiplied every day in 30 days.
Instructional Design

Desmos Activity: **Match My Exponential !!!**

**Engage**

For each Match My Exponential challenge, plot an exponential function that passes through the given points.

Let's get started!

**Teacher Moves**

Use the summary view on the dashboard to identify students who may need help.

Students who employ guess-and-check may end up with something that looks correct (e.g., $y = 2.99^x$) but registers as incorrect. Encourage those students to verify their answer numerically. For example, substitute $x = 0$ and $x = 1$ into their function, and compare the results to the target points in the coordinate plane.

Note: This activity is designed to introduce students to equations of the form $y = b^x$ and $y = a \cdot b^x$. However, while it is not a point of emphasis, students may use any exponential form—including shifted exponential functions of the form $y = a \cdot b^x + c$—to solve any of the challenges. This may produce particularly interesting results in the Challenge Creator at the end of the activity.

**Sample Responses**

\[ y = 3^x \]
Synchronous: Complete during a classroom discussion while pausing the activity to highlight student responses.

Asynchronous: Introduce the problem to students in a virtual platform; this can be done via e-document or video. Allow students to share responses within the Desmos platform and provide feedback via the teacher dashboard. Additionally, students could use audio/video to share. Provide feedback to individual student responses and highlight multiple strategies used by students.

Unplugged/Offline: Provide the images on slides two and three for students to engage in the task. Have students share ideas through email/text/phone. Provide feedback to students and share other students’ ideas before engaging in the remaining sections.
Explore

4 Settle a Dispute

Mark thinks equation \( f(x) = 4^x \) will match the solid graph.
Mia thinks it will match the dotted red graph.

Who is correct?

Teacher Moves

Use the teacher view in the dashboard to see a distribution of student choices and a summary of their responses.

Highlight some of the best arguments for each choice. Ask students to respond with counterarguments.

Sample Responses

Neither student is correct. Mark’s graph passes through \((1,3)\), but \( y = 4^x \) should pass through \((1,4)\). Mia’s graph passes through \((0,4)\), but \( y = 4^x \) should pass through \((0,1)\).

5 Challenge #3: Adjust …

Hint: Exponential function format is: \( a \cdot b^x \)

- \( a \) is the initial value (y-intercept)
- \( b \) is the base multiplier

Example: \( f(x) = 6 \cdot 5^x \) begins at \((0,6)\) y-value = 6

The next point is \((1,30)\) the y-value is 30 \( (y = 6 \cdot 5^1) \)

Teacher Moves

Use the summary view on the dashboard to identify students who may need help.

Sample Responses

\( y = 4 \cdot 3^x \)
Each should pass through the OPEN BLACK POINT and one of the other four points. (One is done for you.)

When you're ready, press "Check My Work."

Hint: Click points to see how y-values change

**Teacher Moves**

Use the summary view of the dashboard to check student progress. Offer individual support where needed, or lead a whole-class discussion if enough students are struggling.

Use the teacher view to look at individual student work. Consider showing a correct response and asking students to make connections between the parameters in the equations and the behavior of the graphs. Or show a partially correct response and ask the class: "Which of these equations are correct? How can we fix the ones that are not?"

**Sample Responses**

In no particular order:

- \( y = 2 \cdot 4^x \)
- \( y = 1 \cdot 8^x \)
- \( y = 16 \cdot \left( \frac{1}{2} \right)^x \)
- \( y = 6 \cdot \left( \frac{4}{3} \right)^x \)
What is the equation of the graph shown here?

Hint: Exponential function format is: \( a \cdot b^x \)
\( a \) is the initial value (y-intercept)
\( b \) is the base multiplier

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**Teacher Moves**

Use the teacher view in the dashboard to see a distribution of student choices and a summary of their responses.

Highlight several student responses for the class. Start with informal math language and reasoning, then move to more formal responses.

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**Sample Responses**

- The graph starts at 3 and multiplies by 2 to get each new value. So the equation is \( y = 3 \cdot 2^x \).
- The intercept is \((0,3)\), so the coefficient is 3. The graph passes through \((1,6)\), so the base is \(\frac{6}{3} = 2\). (In other words, every time the \(x\)-value increases by 1, the \(y\)-value is multiplied by 2.) Therefore, the equation is \( y = 3 \cdot 2^x \).

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- **Synchronous**: Complete Desmos activity during synchronous learning, either face to face, virtual, or blended.
- **Asynchronous**: Using the teacher dashboard, unrestrict screens four through seven. Give students time to complete the screens and provide feedback. Ensure that enough time is provided for students to participate and respond to your feedback and edit responses as needed.
- **Unplugged/ Offline**: Provide paper/electronic versions of the graphs presented on screens four through seven. Allow students time to complete the work and submit through email/text or other means. Provide feedback and share with other students and provide access to other students’ thinking.

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**Apply**

**Teacher Moves**

Two different hints are offered for students who press "try it" with an incorrect response:

Make Y-coordinate differences TRIPLE as you move to the right.
Evaluate the function when \(x = 1\): \(f(1) = 3^1\)

**Sample Responses**

Student moves point to \((1,3)\).
Teacher Moves

9 Move the GREEN point...

Two different hints are offered for students who press "try it" with an incorrect response:

Make Y-coordinate differences QUADRUPLE as you move to the right.
Evaluate the function when \( x = 1 \): \( f(1) = 4^1 \)

Sample Responses

Student moves point to (1,4)

Teacher Moves

10 PRACTICE! See No...

Encourage students to explore how the equation changes when the asymptote moves.

Sample Responses

Response will vary, as the constant is randomized in the equation.

11 Move the Asymptote

Sample Responses

Response will vary, as the constant is randomized in the equation.

12 Move the Asymptote

Sample Responses

Response will vary, as the constant is randomized in the equation.

13 Match the graph to t...

Teacher Moves

Two different hints are offered for students who press "try it" with an incorrect response:

Make Y-coordinate differences DOUBLE as you move to the right.
Evaluate the function when \( x = 1 \): \( f(1) = 2^1 + 1 \)

14 Match the graph to t...

Teacher Moves

Two different hints are offered for students who press "try it" with an incorrect response:

Make Y-coordinate differences QUINTUPLE as you move to the right.
Evaluate the function when \( x = 1 \): \( f(1) = 5^1 + 1 \)
**Teacher Moves**

**Students will receive feedback for partially correct answers.**

**Sample Responses**

**Student answers will vary (randomized constant)**

- **Synchronous:** Complete Desmos activity during synchronous learning, either face to face, virtual, or blended.
- **Asynchronous:** Using the teacher dashboard, unrestrict screens eight through 15. Give students time to complete the screens and provide feedback. Ensure that enough time is provided for students to participate and respond to your feedback and edit responses as needed.
- **Unplugged/Offline:** Provide students with access to graph paper and allow students to engage in the questions presented on screens eight-15. Ask students to complete the questions and have them submit responses via email/text/phone. Provide feedback, share these responses with other students, and share other students’ responses with them.

**Reflect**

<table>
<thead>
<tr>
<th>16 Class Gallery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Moves</td>
</tr>
</tbody>
</table>

**Here students will create their OWN challenges and solve challenges from their classmates. We recommend students complete the rest of the activity before creating their challenge. We anticipate this Challenge Creator will add 30 minutes to the duration of the activity.**

Encourage students to complete each other’s challenges but also to take some time to review responses to their own. Use the teacher dashboard to look for unique challenges and unique solutions that may expand your students’ understanding of the mathematics. Highlight those for students and also ask them what they learned from the experience.

We intend for this to be a social and creative experience for students. We encourage you to emphasize those virtues whenever you see them in your class.

Students will create their own exponential challenges and they will also solve challenges from classmates. Students will be encouraged to reflect upon other’s responses to the challenge they created.

- **Synchronous: Challenge creation and reflection.** Students will use slide 16 to create a challenge problem. Other students will have the opportunity to choose a classmate’s challenge from the galley. Students are free to solve multiple challenges and to reflect upon solutions to the challenge they created.
- **Asynchronous: Challenge creation and reflection.** Students will also use slide 16 to create a challenge problem. Other students will have the opportunity to choose a classmate’s challenge from the galley. Students are free to solve multiple challenges and to reflect upon solutions to the challenge they created.
- **Unplugged/Offline:** Students will be encouraged to create exponential equations based on a given y-intercept and another point. They can check these equations by applying their exponential function rule for both selected points. Further reflection can be relayed by email.
### Evidence of Student Success

**Formative Assessment Questions:**
- Can you create an exponential function given two points?
- How does the asymptote impact the equation of an exponential function?
- What types of bases cause exponential growth and decay?
- Can you find the end behavior of an exponential function?
- How does the y-intercept impact the equation of an exponential function?
- Why does exponential growth increase more rapidly than linear growth?

### Student Learning Supports

**Establish mathematics goals to focus learning.**
- Make instructions and expectations clear for the activities.
- Make explicit connections between current and prior lessons or units.

**Facilitate meaningful mathematical discourse.**
- Explicitly model and teach good “discussion board” etiquette.

**Pose purposeful questions.**
- Predetermine when you will call on the student or use the pause feature within the activities.
- Break class into small discussion groups to work collaboratively and then have groups report back to the whole group.

**Support productive struggle in learning mathematics.**
- Offer outlines and other scaffolding tools and share tips that might help students learn.
- Provide feedback using the feedback feature within activities and offer corrective opportunities.
- Consider the pacing of the lesson.

**Elicit and use evidence of student thinking.**
- Anticipate any misconceptions or questions students might have about the task, materials or technology. Proactively address them with readily available and accessible resources such as Exponential functions notes and practice Math is Fun. Students can complete the interactive Mathopolis practice at the bottom of the lesson.
### Engaging Families

- Students and families can gain further understanding of exponential models by interacting with these Desmos graphs: [Exponential Model](#), [Exponential Growth and Decay](#), [Transformations of Exponential Functions](#). The graphs are all interactive. Families can explore how exponential graphs and equations change as the rate of growth/decay increases and decreases.

- Exponential functions notes and practice: [Mathbits](#). Self-checking practice problems are available on this site. The questions are printer friendly.

- Watch and discuss this video on exponential growth and decay involving [Zombies](#)!