Grade Level/Course: Algebra 1

Lesson/Unit Plan Name: Graphing Exponential Functions

Rationale/Lesson Abstract: Students will graph exponential functions, identify key features and learn how the variables *a*, *h* and *k* in $f(x)=a\cdot b^{x-h}+k$ affect the parent graph $f(x)=b^x$.

Timeframe: 3 class periods

Day 1 focus: Graphing functions of the form $f(x)=b^x$ and $f(x)=\left(\frac{1}{b}\right)^x$ for $b=2, 3, 4$.

Day 2 focus: Graphing functions of the form $f(x)=a\cdot b^x$.

Day 3 focus: Graphing functions of the form $f(x)=a\cdot b^{x-h}+k$.

Common Core Standard(s):

F-IF.7e Graph exponential and logarithmic functions, showing intercepts, end behavior, and trigonometric functions, showing period, midline, and amplitude.★

F-BF.3 Identify the effect on the graph of replacing $f(x)$ by $f(x)+k$, $kf(x)$, $f(kx)$, 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.*

Notes: A Warm-Up is on page 22.
For Day 2, use the blank grid handout for example 3 and try problem.

Instructional Resources/Materials:

Warm-Up
Daily Student Graphing Handout (2 options)
Daily Student Exit Ticket (strip)
Graphing Tool (optional)

Lesson Day 1

Think-Pair-Share: List all that you know about the function $h(x)=x^2$. Then compare $h(x)=x^2$ to $f(x)=2^x$ and predict what the graph $f(x)=2^x$ of is going to look like.

Possible Descriptions of $h(x)=x^2$:

- $h(x)$ is a quadratic function.
- The graph is a parabola that has a vertex and an axis of symmetry.

Compare $h(x)=x^2$ to $f(x)=2^x$:

- x is the base in $h(x)$ and the exponent in $f(x)$, 2 is the exponent of $h(x)$ and the base in $f(x)$

Discuss the graph of $f(x)=2^x$:

- Show the graph of $f(x)=2^x$ on a graphing tool. Discuss the key features (domain, range, etc). Use the table of values to duplicate the graph onto handout.
- If no technology is available, proceed to Example 1 and create the graph using a table.

<u>Example 1:</u> Graph the function $f(x)=2^x$.

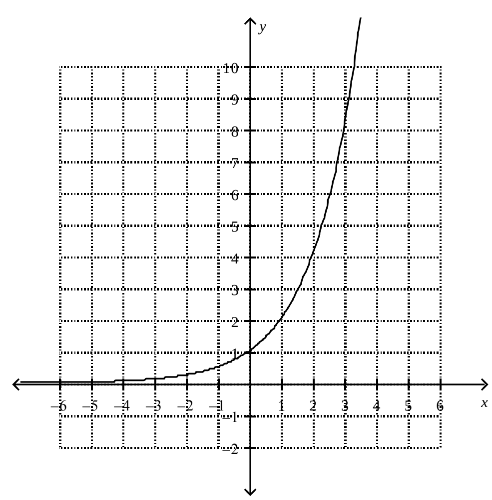
x	$f(x)=2^x$	$(x,\ f(x))$
-2	$f(-2)=2^{-2}$ $=\left(\frac{1}{2}\right)^2$ $=\frac{1}{4}$	$\left(-2,\ \frac{1}{4}\right)$
-1	$f(-1)=2^{-1}$ $=\left(\frac{1}{2}\right)^1$ $=\frac{1}{2}$	$\left(-1,\ \frac{1}{2}\right)$
0	$f(0)=2^0$ $=1$	$(0,1)$
1	$f(1)=2^1$ $=2$	$(1,2)$
2	$f(2)=2^2$ $=2\cdot 2$ $=4$	$(2,4)$
3	$f(3)=2^3$ $=2\cdot 2\cdot 2$ $=8$	$(3,8)$

<u>Input-Output Table:</u>

Create a 3 column table:

- Choose non-negative inputs to start.
- Choose a few non-positive input values and review the properties $a^0=1$ and $a^{-n}=\left(\frac{1}{a}\right)^n$.

Notice that as *x* decreases, $f(x)$ approaches zero. The line $y=0$, or the *x*-axis, is called a horizontal <u>asymptote</u>.

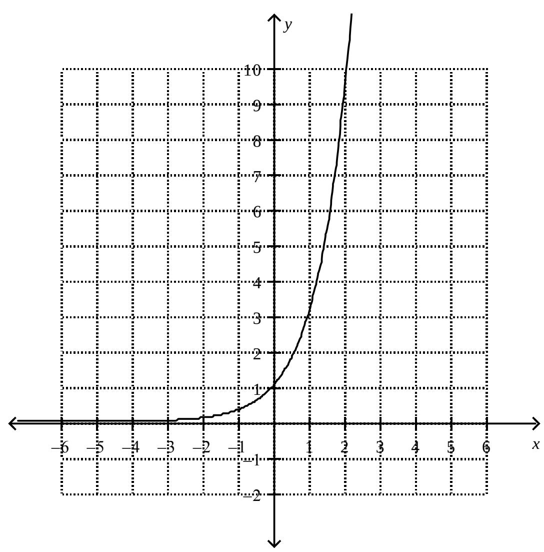


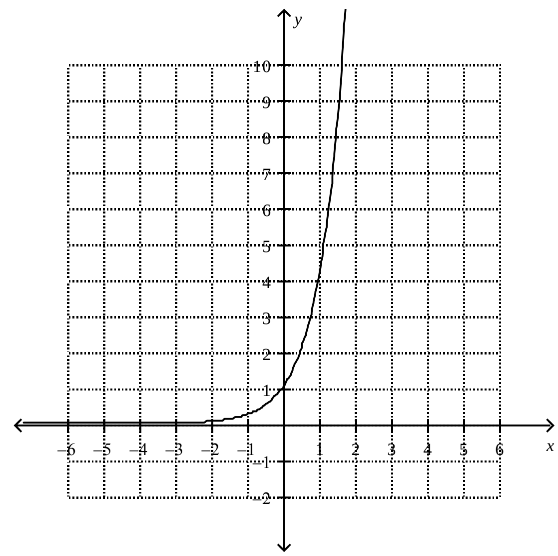
An <u>exponential function</u> is a function of the form $y = a \cdot b^x$ where $a \neq 0$, $b > 0$ and $b \neq 1$.

*For this lesson $a = 1$ and $y = b^x$

<u>Try:</u> Partner A: $f(x) = 3^x$ Partner B: $f(x) = 4^x$

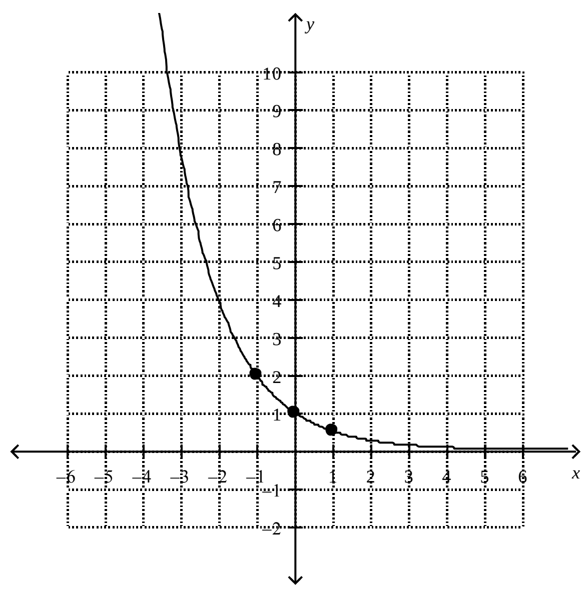
Think-Pair: What kind of functions are they? Explain.
Predict what each graph is going to look like.
Each partner graphs their function.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.





<u>Example 2:</u> Graph the function $g(x) = \left(\frac{1}{2}\right)^x$.

x	$f(x) = \left(\frac{1}{2}\right)^x$	$(x,\ f(x))$
-1	$f(-1) = \left(\frac{1}{2}\right)^{-1} = \left(\frac{2}{1}\right)^1 = 2$	$(-1,\ 2)$
0	$f(0) = \left(\frac{1}{2}\right)^0 = 1$	$(0,\ 1)$
1	$f(1) = \left(\frac{1}{2}\right)^1 = \frac{1}{2}$	$\left(1,\ \frac{1}{2}\right)$



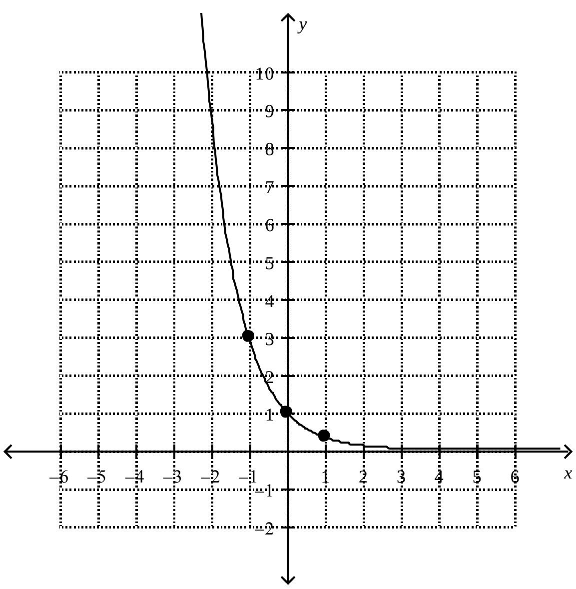
How are the functions $g(x)=\left(\frac{1}{2}\right)^x$ and $f(x)=2^x$ related?

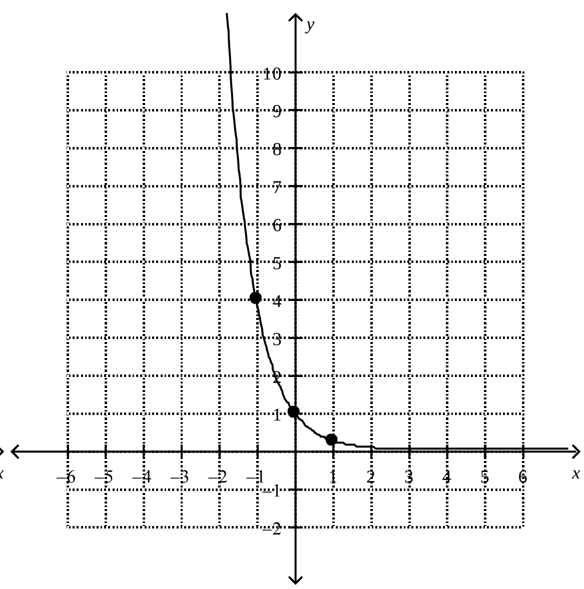
- They are exponential functions of the form $f(x)=b^x$.
- Their graphs have the same shape, y-intercept and asymptote at $y=0$.
- Their bases are reciprocals.
- Their graphs are reflections about the y-axis.

Identify other points on $f(x)=\left(\frac{1}{2}\right)^x$: $(-3, 8)$, $(-2, 4)$, $\left(2, \frac{1}{4}\right)$, and $\left(3, \frac{1}{8}\right)$.

<u>Try:</u> Partner A: $g(x)=\left(\frac{1}{3}\right)^x$ Partner B: $g(x)=\left(\frac{1}{4}\right)^x$

Think-Pair: What kind of functions are they? Explain.
Predict what each graph is going to look like.
Each partner graphs their function. <u>Hint:</u> Use the previous graphs for reference.
Identify the key features of each graph.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.





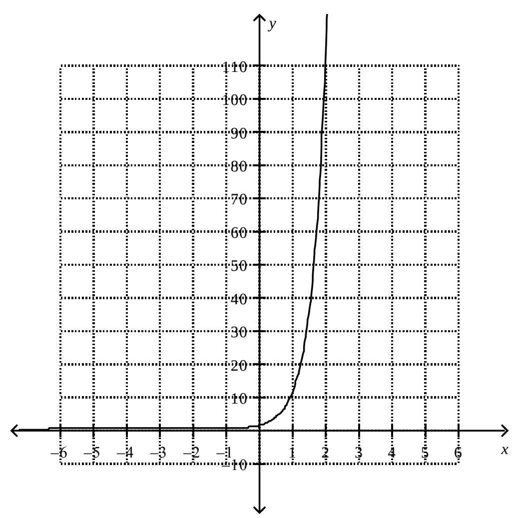
<u>Note:</u> Students might identify the pattern (geometric sequence) created in the tables of the function $f(x)=b^x$. The common ratio could be used to generate the outputs quickly.

<u>Generalize:</u> The graph of $f(x) = b^x$ goes through the points $\left(-1, \frac{1}{b}\right)$, $(0, 1)$, and $(1, b)$. So knowing the shape of the graph, these three points are sufficient to graph the function.

<u>Key Features</u> of $f(x) = b^x$:	
Domain:	All Real Numbers $x \in \Re$ or $\{x \mid x \in \Re\}$
Range:	All Positive Real Numbers $f(x) > 0$ or $\{y \mid y > 0\}$
Intercept(s):	No *x*-intercept, *y*-intercept is $(0, 1)$
Asymptote:	$y = 0$
End Behavior when $b > 1$**:**	As *x* increases, $f(x)$ increases. As *x* decreases, $f(x)$ approaches zero.
End Behavior when $0 < b < 1$**:**	As *x* increases, $f(x)$ approaches zero. As *x* decreases, $f(x)$ increases.

Recommended: Revisit graphs. Write/discuss the key features of each.

<u>Example 3:</u> Write the function whose graph is given.



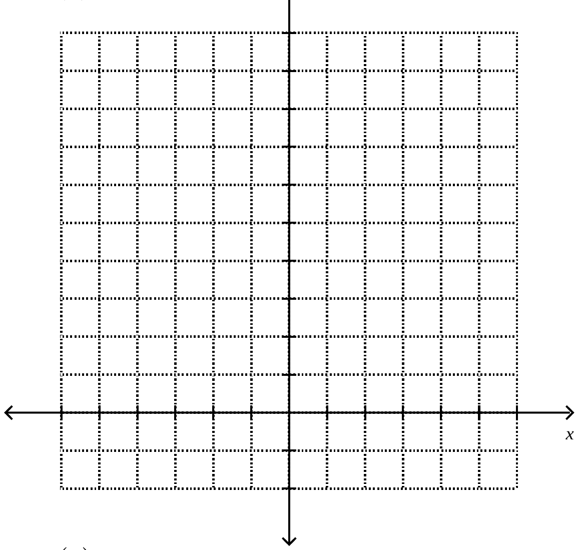
Think-Pair: What kind of function does the graph represent?
Make a conjecture about the *b* value in $f(x) = b^x$.
Identify a point or points on the graph.

Solution: This is going to be an exponential function like those in example 1, where $b > 1$. Two points on the graph are $(1, 10)$ and $(2, 100)$. Notice that we can write the points as $(1, 10^1)$ and $(2, 10^2)$. I predict that any point on the graph is $(x, 10^x)$. Therefore, the graph could be modeled by the function $f(x) = 10^x$.

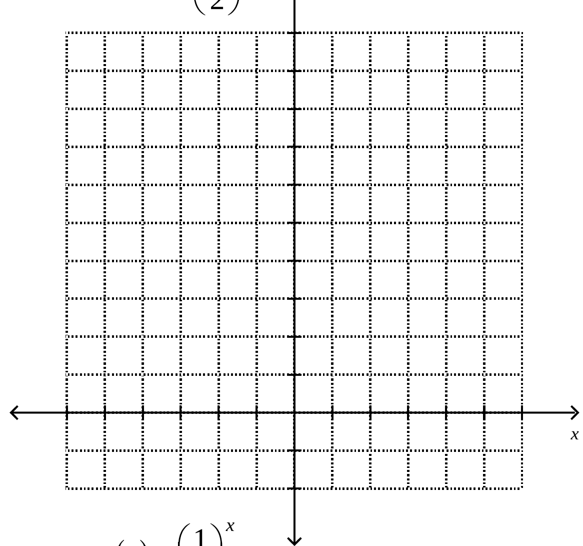
EXIT TICKET: Identify the key features of the graph of $f(x) = \left(\frac{1}{5}\right)^x$.

Graphing Exponential Functions (Day 1)

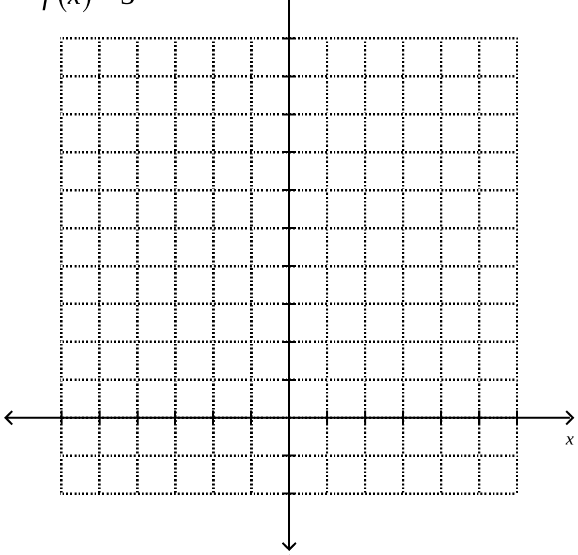
$f(x) = 2^x$



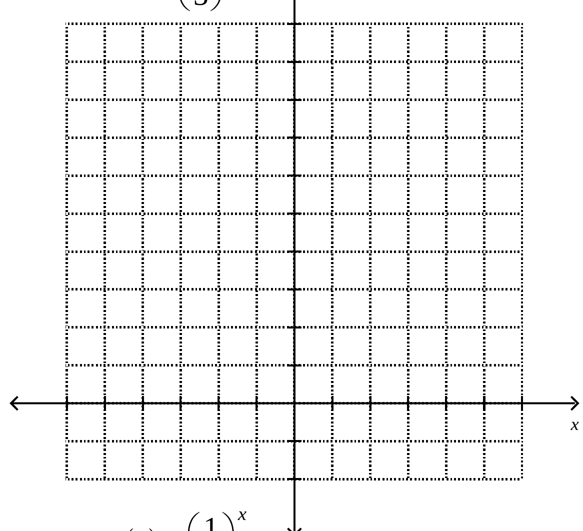
$g(x) = \left(\frac{1}{2}\right)^x$



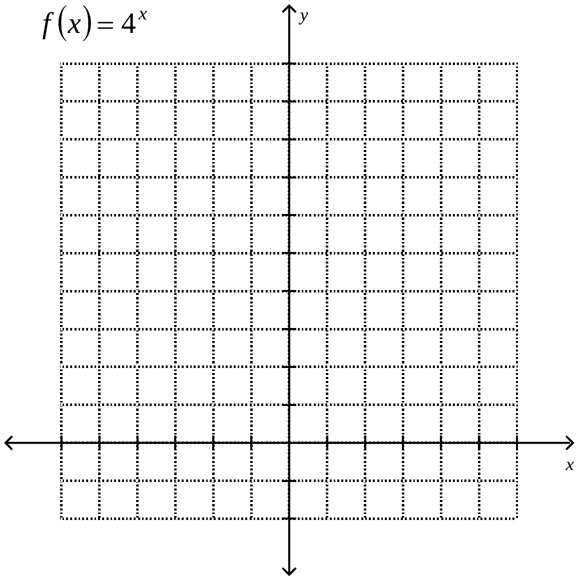
$f(x) = 3^x$



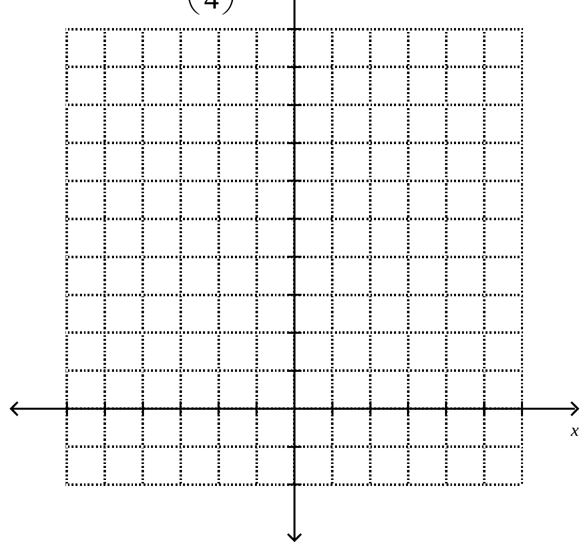
$g(x) = \left(\frac{1}{3}\right)^x$



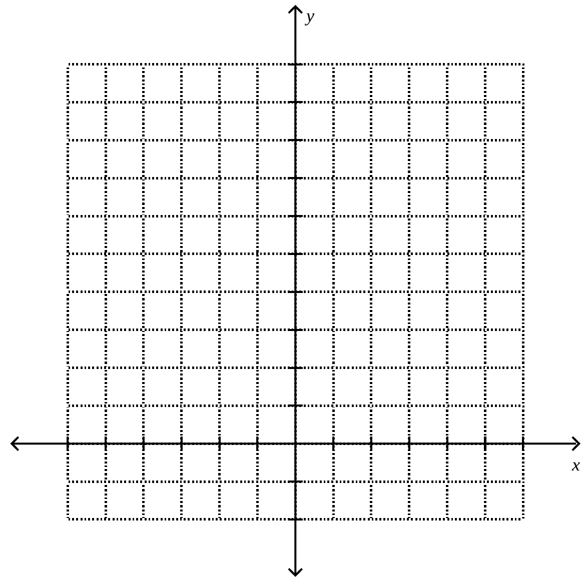
$f(x) = 4^x$

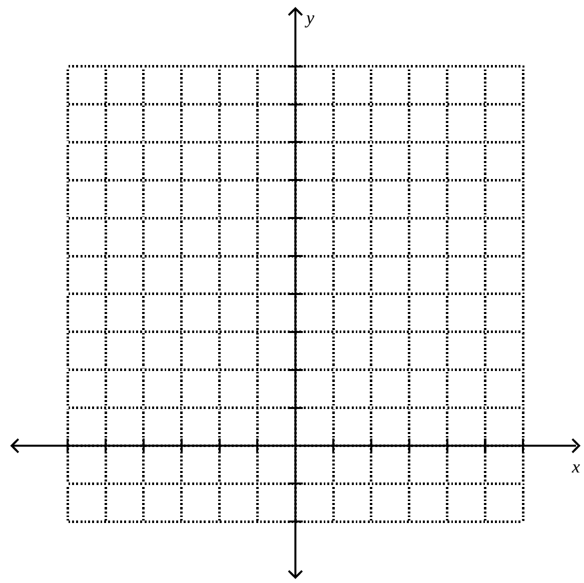


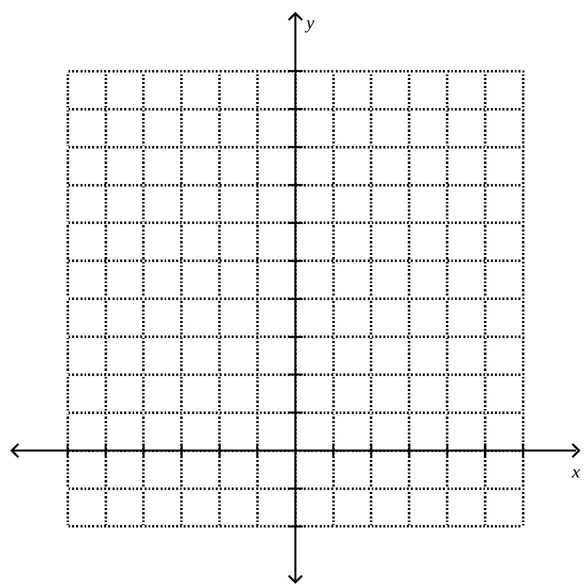
$g(x) = \left(\frac{1}{4}\right)^x$



Graphing Exponential Functions (Day 1)







Lesson Day 2

Think-Pair-Share: Review the graphs from Day 1. Compare the functions $f(x)$ and $g(x)$.

- How would you classify (or name) the functions $f(x)$?
- How would you classify (or name) the functions $g(x)$?

Similarities between the functions $f(x)$ and $g(x)$:

- They are all exponential functions.
- Their graphs have the same shape.
- They have the same domain, range, *y*-intercept and asymptotes.

Major Difference between the functions $f(x)$ and $g(x)$: End behavior

- $f(x)$ increases from left to right. Specifically, as $x \to \infty$, $f(x) \to \infty$.
- $g(x)$ decreases from left to right. Specifically, as $x \to \infty$, $g(x) \to 0$.

An <u>exponential growth function</u> is a function of the form $f(x) = a \cdot b^x$ where $a > 0$ and $b > 1$.

An <u>exponential decay function</u> is a function of the form $f(x) = a \cdot b^x$ where $a > 0$ and $0 < b < 1$.

<u>Example 1:</u> Graph the function $h(x) = 3 \cdot 2^x$.

Think-Pair: What kind of function is $h(x)$? Explain.
Predict what the graph is going to look like.
How is the 3 going to affect the graph?

<u>Input-Output Table:</u>

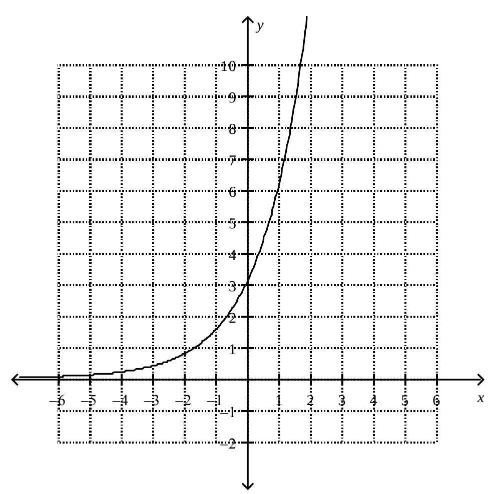
- Refer to the table of $f(x) = 2^x$.
- Create a similar table for $h(x) = 3 \cdot 2^x$.
- Discuss $h(x) = 3 \cdot f(x)$: the outputs of $h(x)$ are 3 times the outputs of $f(x)$. Find the outputs of $h(x)$ by multiplying the outputs of $f(x)$ by 3.

$f(x) = 2^x$

x	2^x
-2	$\frac{1}{4}$
-1	$\frac{1}{2}$
0	1
1	2
2	4

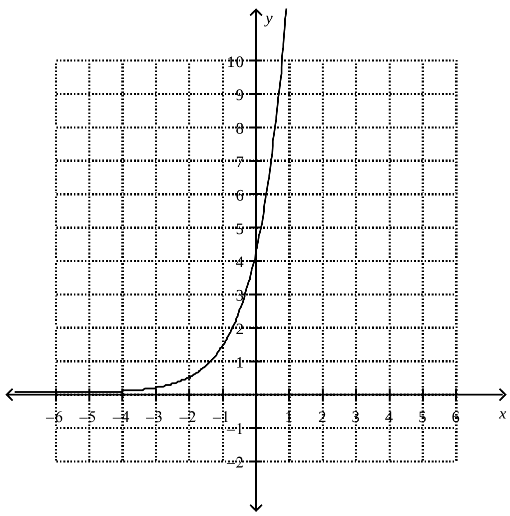
$h(x) = 3 \cdot 2^x$

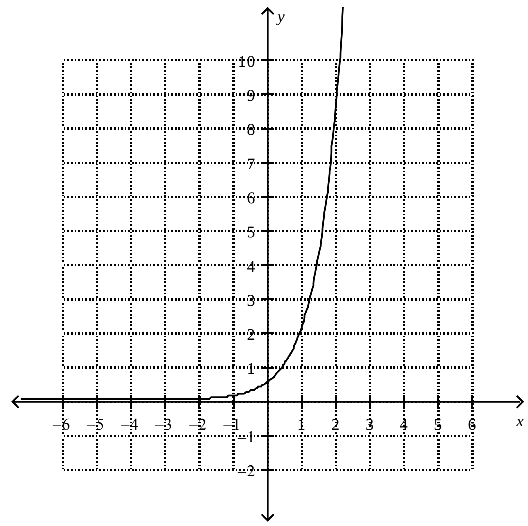
x	$3 \cdot 2^x$	$(x, h(x))$
-2	$3 \cdot \frac{1}{4} = \frac{3}{4}$	$\left(-2, \frac{3}{4}\right)$
-1	$3 \cdot \frac{1}{2} = \frac{3}{2}$	$\left(-1, \frac{3}{2}\right)$
0	$3 \cdot 1 = 3$	$(0, 3)$
1	$3 \cdot 2 = 6$	$(1, 6)$
2	$3 \cdot 4 = 12$	$(2, 12)$



Try: Partner A: $h(x) = 4 \cdot 3^x$ Partner B: $h(x) = \frac{1}{2} \cdot 4^x$

Think-Pair: What kind of functions are they? Explain.
Predict what each graph is going to look like.
Each partner graphs their function. Hint: Use previous graphs for reference.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.





Discuss: How does the value of "*a*" affect the graph of an exponential function?
[The value of "*a*" changes the *y*-intercept and stretches or compresses the graph.]

Input-Output Table:

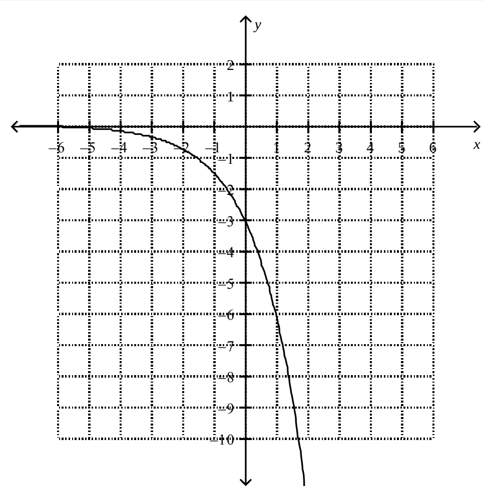
- Refer to the table of $h(x) = 3 \cdot 2^x$.
- Create a table for $g(x) = -3 \cdot 2^x$.
- Discuss $g(x) = -1 \cdot h(x)$: the outputs of $g(x)$ are the opposite of the outputs of $h(x)$. Find the outputs of $g(x)$ by multiplying the outputs of $h(x)$ by -1.

Example 2: Graph the function $g(x) = -3 \cdot 2^x$.

Think-Pair: What kind of function is $g(x)$? Explain.
Predict what the graph is going to look like.
How is the -3 going to affect the graph?
How is $g(x) = -3 \cdot 2^x$ related to $h(x) = 3 \cdot 2^x$?

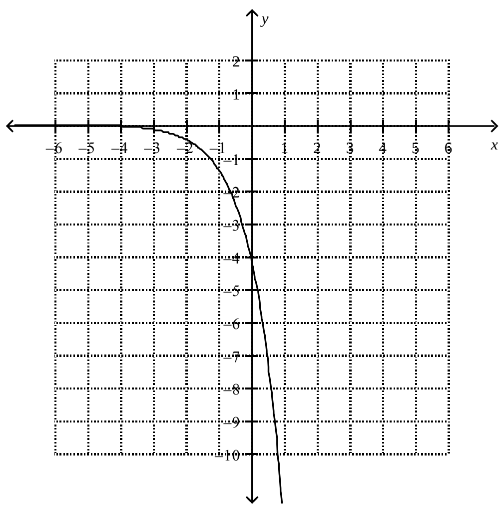
$g(x) = -3 \cdot 2^x$

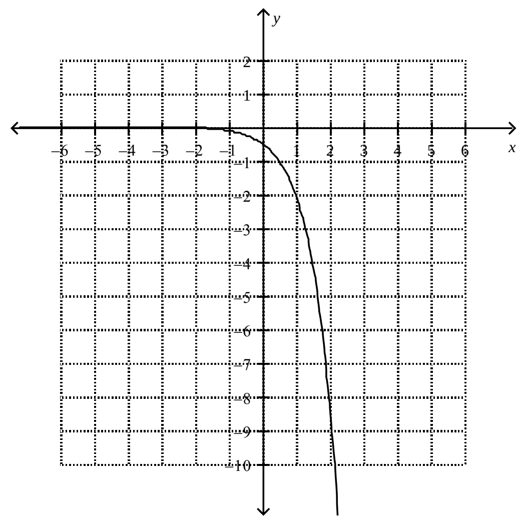
x	$-3 \cdot 2^x$	$(x, g(x))$
-2	$-3 \cdot \frac{1}{4} = -\frac{3}{4}$	$\left(-2, -\frac{3}{4}\right)$
-1	$-3 \cdot \frac{1}{2} = -\frac{3}{2}$	$\left(-1, -\frac{3}{2}\right)$
0	$-3 \cdot 1 = -3$	$(0, -3)$
1	$-3 \cdot 2 = -6$	$(1, -6)$
2	$-3 \cdot 4 = -3$	$(2, -12)$



Try: Partner A: $g(x) = -4 \cdot 3^x$ Partner B: $g(x) = -\frac{1}{2} \cdot 4^x$

Think-Pair: What kind of functions are they? Explain.
Predict what each graph is going to look like.
How will you graph each function?
Each partner graphs their function. Hint: Use the previous graphs for reference.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.





Discuss: How do the graphs compare when a is positive to when a is negative?
Identify some points on the graph of $f(x) = a \cdot b^x$.

- When $a > 0$, the function values are positive and when $a < 0$ the function values are negative.
- $f(x) = a \cdot b^x$ contains the points $\left(-1, \frac{a}{b}\right)$, $(0, a)$, and $(1, ab)$.

Key Features of $f(x) = a \cdot b^x$:

Domain: All Real Numbers $x \in \Re$ or $\{x \mid x \in \Re\}$

Range: If $a > 0$: All Positive Real Numbers $f(x) > 0$ or $\{y \mid y > 0\}$
If $a < 0$: All Negative Real Numbers $f(x) < 0$ or $\{y \mid y < 0\}$

Intercept(s): No x-intercept and y-intercept at $(0, a)$

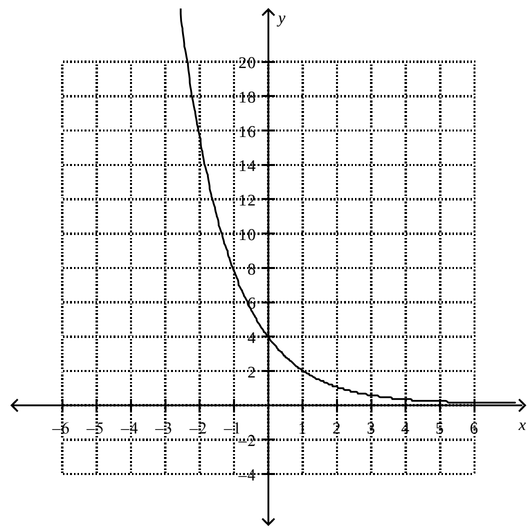
End Behavior: The end behavior depends on a and b; discuss the 4 cases (see Exit Ticket).
For example, where does the function approach zero?
If $b > 1$: as x decreases, $f(x)$ approaches zero.
If $0 < b < 1$: as x increases, $f(x)$ approaches zero.

Asymptote: $y = 0$

Example 3: Graph the function $f(x)=4\left(\frac{1}{2}\right)^x$:

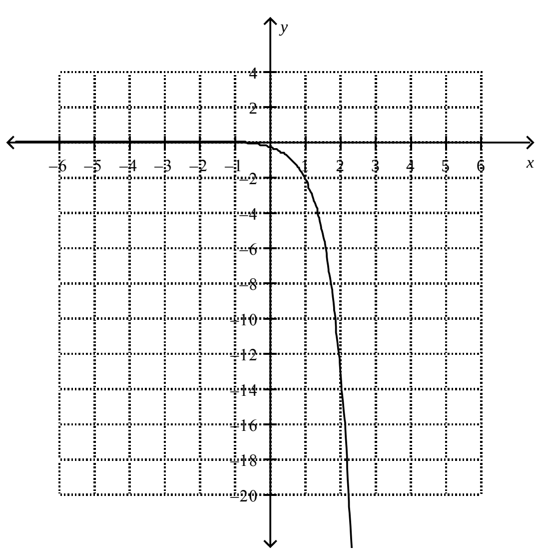
a) Identify and find function values of the parent function.
b) Identify the points of the transformed function.
c) Determine how to draw and label axes.

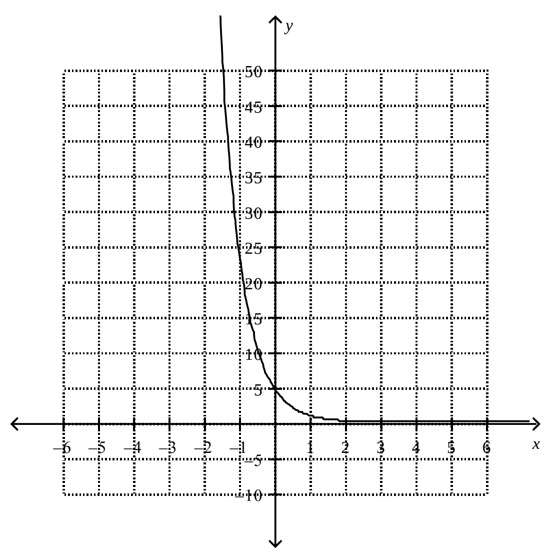
x	$\left(\frac{1}{2}\right)^x$	$4\left(\frac{1}{2}\right)^x$	$(x,\ f(x))$
-2	$\left(\frac{1}{2}\right)^{-2}=4$	$4(4)=16$	$(-2,16)$
-1	$\left(\frac{1}{2}\right)^{-1}=2$	$4(2)=8$	$(-1,8)$
0	$\left(\frac{1}{2}\right)^{0}=1$	$4(1)=4$	$(0,4)$
1	$\left(\frac{1}{2}\right)^{1}=\frac{1}{2}$	$4\left(\frac{1}{2}\right)=2$	$(1,2)$
2	$\left(\frac{1}{2}\right)^{2}=\frac{1}{4}$	$4\left(\frac{1}{4}\right)=1$	$(2,1)$



Try: Partner A: $f(x)=-\frac{1}{3}\cdot 6^x$ Partner B: $f(x)=5\cdot\left(\frac{1}{5}\right)^x$

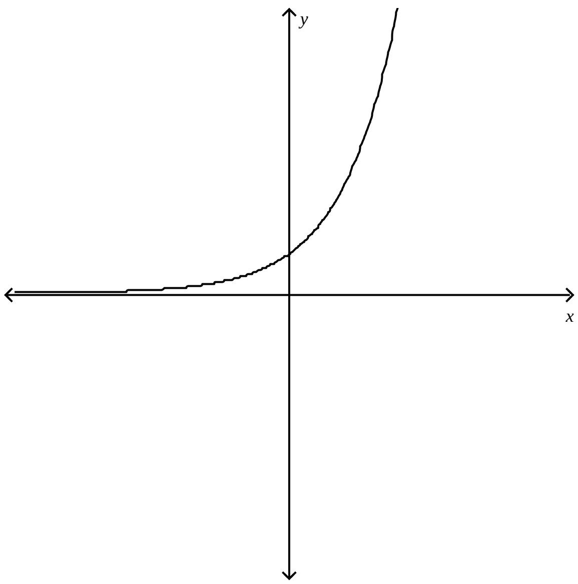
Think-Pair: What kind of functions are they? Explain.
Predict what each graph is going to look like.
How will you graph the function?
How will you draw and label the axes?
Each partner graphs their function.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.



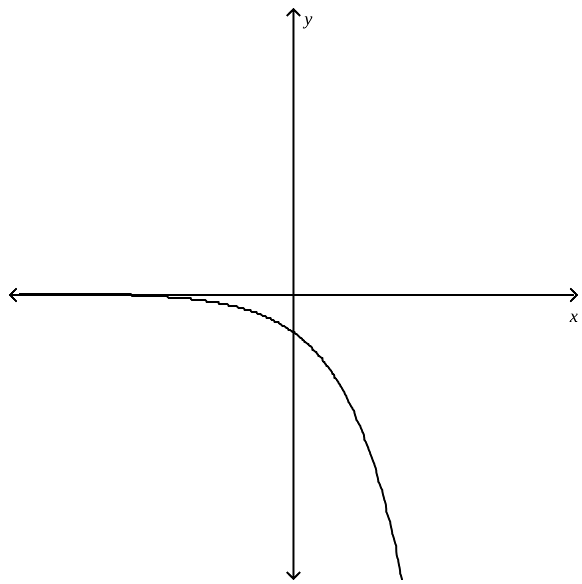


EXIT TICKET: Match the functions to their graphs.

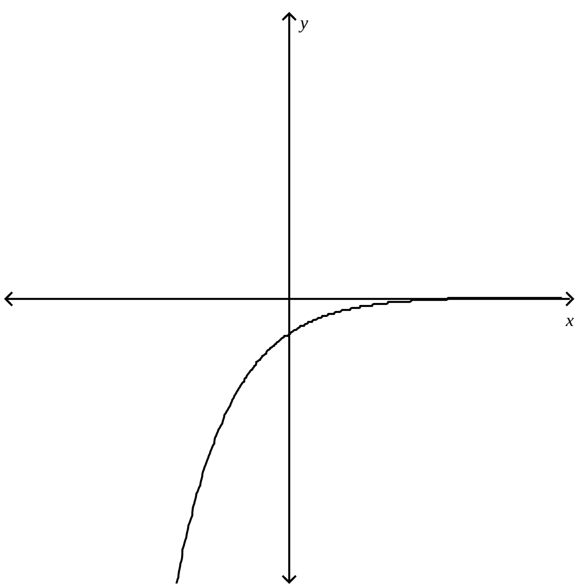
1. $f(x) = -10\left(\frac{1}{6}\right)^x$ 2. $f(x) = -\left(\frac{5}{4}\right)^x$ 3. $f(x) = 9(4.5)^x$ 4. $f(x) = 4\cdot\left(\frac{2}{3}\right)^x$



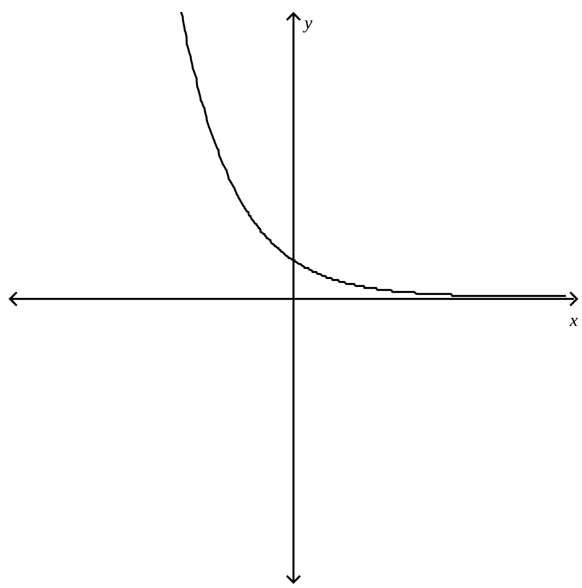
Graph A



Graph B



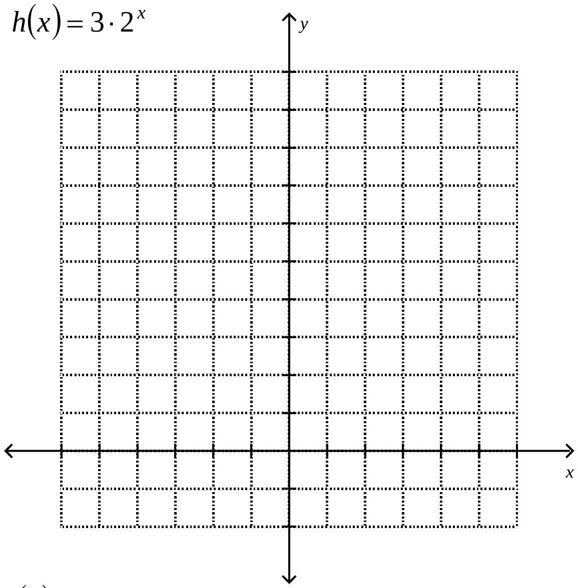
Graph C



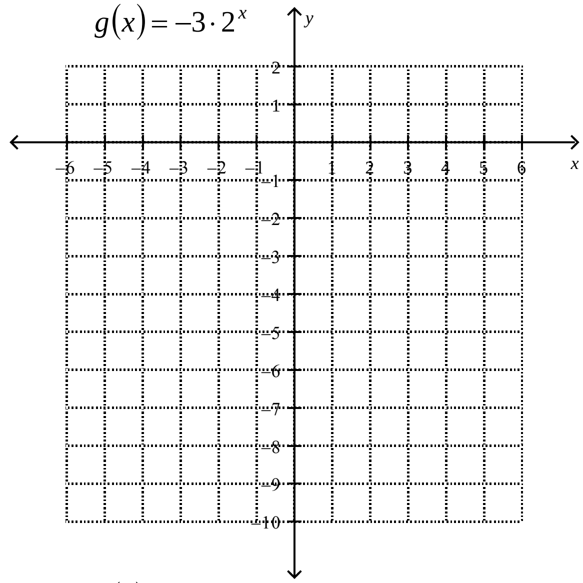
Graph D

Graphing Exponential Functions (Day 2)

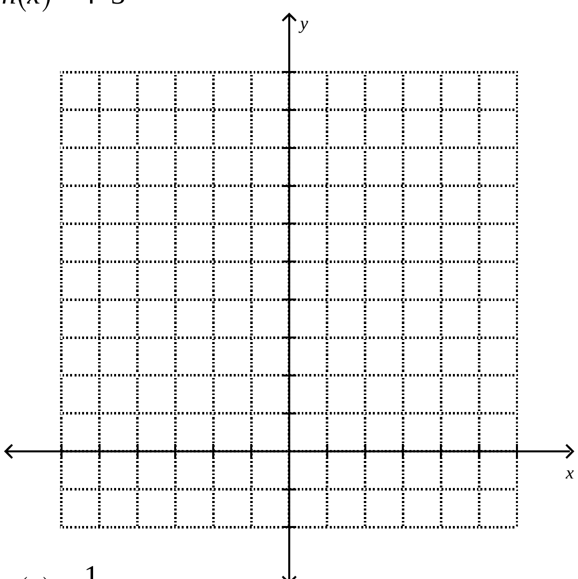
$h(x) = 3 \cdot 2^x$



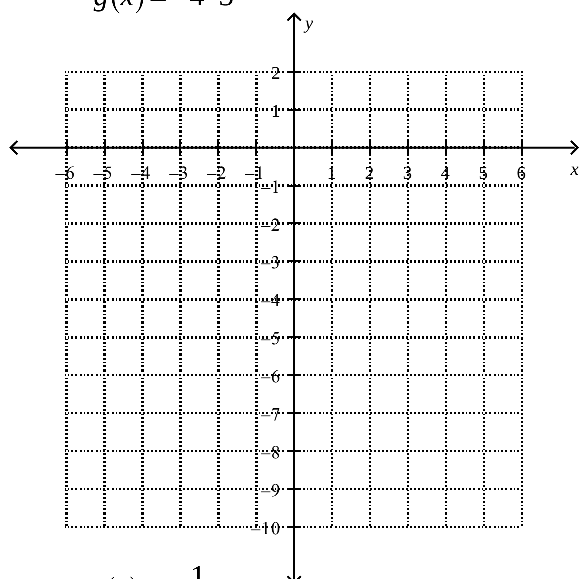
$g(x) = -3 \cdot 2^x$



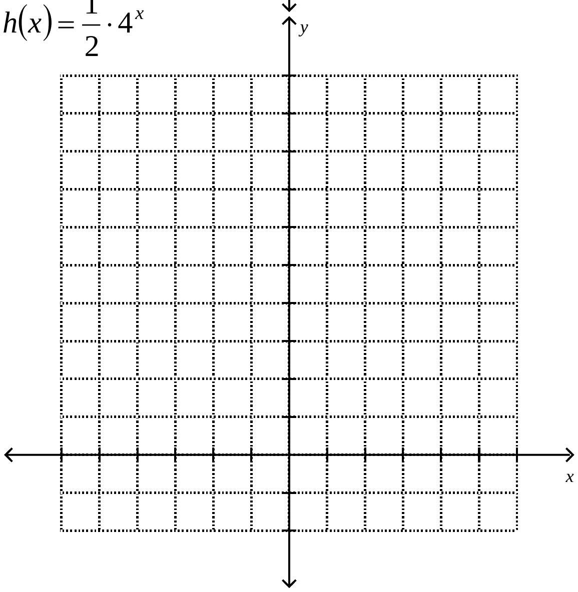
$h(x) = 4 \cdot 3^x$



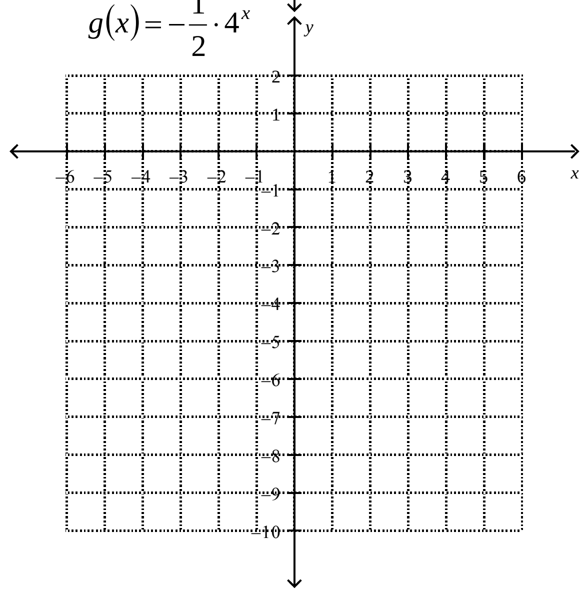
$g(x) = -4 \cdot 3^x$



$h(x) = \frac{1}{2} \cdot 4^x$



$g(x) = -\frac{1}{2} \cdot 4^x$

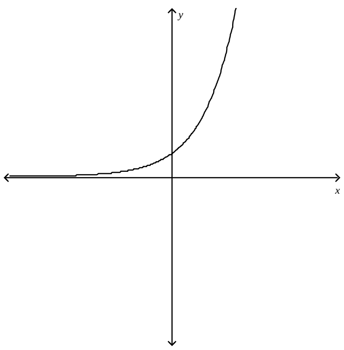


Graphing Exponential Functions (Day 2)

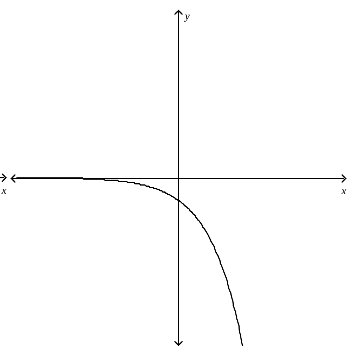
Lesson Day 3

Think-Pair-Share: Each graph below can be written as a function of the form $f(x) = a \cdot b^x$.
What can you determine about the values of *a* and *b* for each graph?

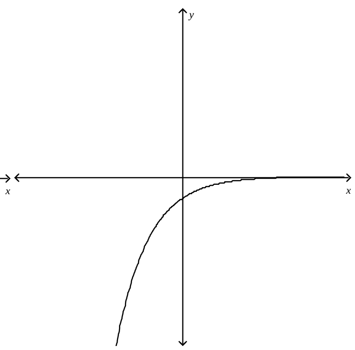
Graph A



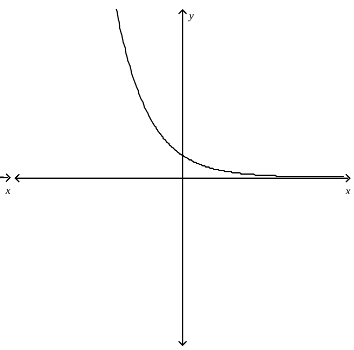
Graph B



Graph C



Graph D



Graph A	**Graph B**	**Graph C**	**Graph D**
$a > 0$ $b > 1$	$a < 0$ $b > 1$	$a < 0$ $0 < b < 1$	$a > 0$ $0 < b < 1$

<u>Example 1:</u> Graph the function $h(x) = 2^x - 3$.

Think-Pair:

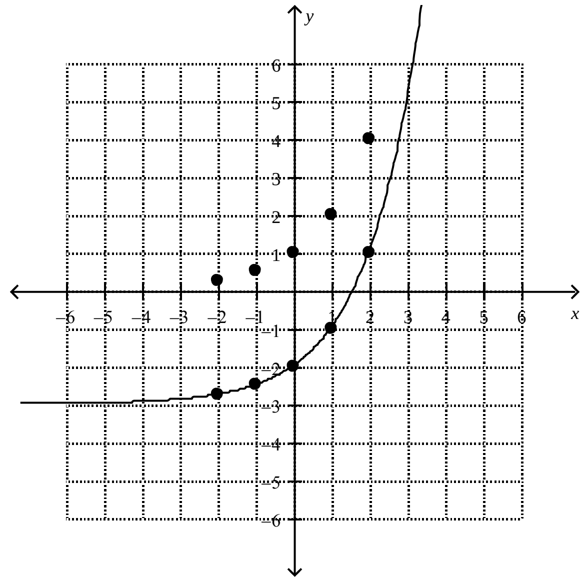
What kind of function is $h(x)$? Explain.
Identify the parent function.
How does the -3 affect the graph?

x	2^x	$2^x - 3$	$(x, h(x))$
-2	$\frac{1}{4}$	$\frac{1}{4} - 3 = -2\frac{3}{4}$	$\left(-2, -2\frac{3}{4}\right)$
-1	$\frac{1}{2}$	$\frac{1}{2} - 3 = -2\frac{1}{2}$	$\left(-1, -2\frac{1}{2}\right)$
0	1	$1 - 3 = -2$	$(0, -2)$
1	2	$2 - 3 = -1$	$(1, -1)$
2	4	$4 - 3 = 1$	$(2, 1)$
3	8	$8 - 3 = 5$	$(3, 5)$

<u>Input-Output Table:</u>

- Review the table of $f(x) = 2^x$.
- Create a similar table for $h(x) = 2^x - 3$.
- Discuss $h(x) = f(x) - 3$: the outputs of $h(x)$ are 3 less than the outputs of $f(x)$. Find the outputs of $h(x)$ by subtracting 3 from the outputs of $f(x)$.
- Another option: graph $f(x)$ and translate the points down 3 units to obtain $h(x)$.

Example 1 continued:



Think-Pair-Share: How do the graphs of the parent function $f(x)=2^x$ and $h(x)=2^x-3$ compare?

Plot the points of the parent function $f(x)=2^x$ is on the same coordinate plane and compare them to $h(x)=2^x-3$. The points of $h(x)$ can be obtained by translating the points of $f(x)$ 3 units down.

Some of the key features of $h(x)=2^x-3$ are:

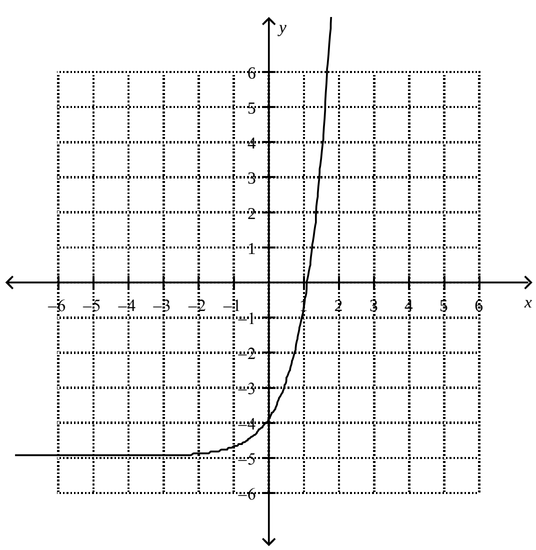
Domain:	**Range:**	**Intercept(s):**	**Asymptote:**
All real numbers	$y>-3$	$(0,-2)$, $\approx(1.5,0)$	$y=-3$

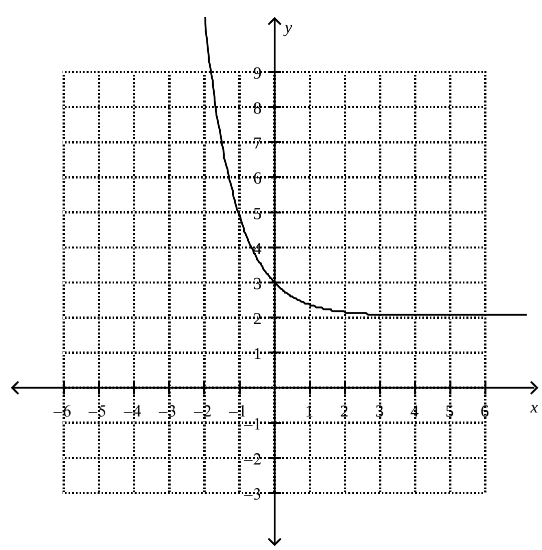
Try: Choose a method and graph the functions.
Method #1- Use an input-output table
Method #2- Translate the graph of the parent function.

Partner A: $h(x)=4^x-5$

Partner B: $h(x)=\left(\frac{1}{3}\right)^x+2$

Think-Pair: What kind of function is $h(x)$? Explain.
Identify the parent function.
Predict what the graph is going to look like.
Each partner graphs their function.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.





Think-Pair-Share: In general, for $f(x)=a\cdot b^x+k$, which key features are affected when $k\neq 0$?

Domain: [No] **Range:** [Yes] **Intercept(s):** [Yes] **Asymptote:** [Yes]

Discuss:

- Draw and label the asymptote on each graph.

$$h(x) = 4^x - 5 \;:\; y = -5 \qquad \text{and} \qquad h(x) = \left(\frac{1}{3}\right)^x + 2 : \; y = 2$$

- How do you determine the asymptote given the function (without graphing)?

  The asymptote of the function $f(x) = a \cdot b^x + k$ is $y = k$

- How does the value of *k* affect the graph of $f(x) = a \cdot b^x + k$?

  The value of *k* is the vertical shift up or down of the parent function *k* units.
  If $k > 0$, then the graph shifts up *k* units. If $k < 0$, then the graph shifts down *k* units.

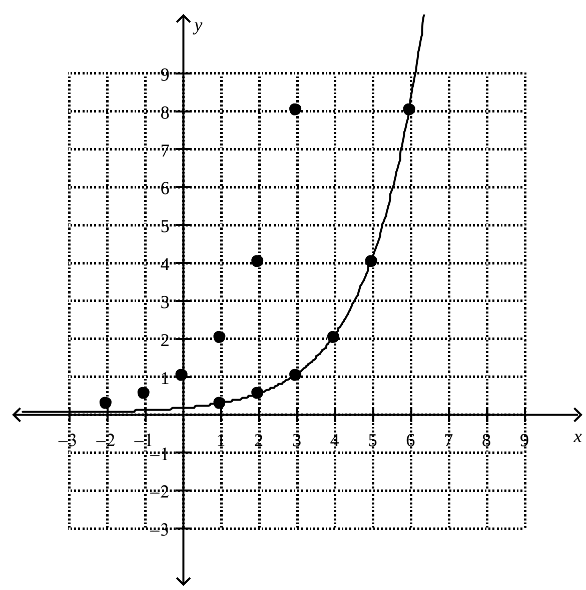
Example 2: Graph the function $g(x) = 2^{x-3}$.

Input-Output Table:

- Start with the *x*-value that makes the exponent zero, or another nonnegative number.
- Then find at least two integer values less than and greater than your starting *x*-value.

Think-Pair: What kind of function is $g(x)$? Identify the parent function.

x	2^{x-3}	$(x, g(x))$
1	2^{1-3} $= 2^{-2}$	$\left(1, \frac{1}{4}\right)$
2	2^{2-3} $= 2^{-1}$	$\left(2, \frac{1}{2}\right)$
3 (Start)	2^{3-3} $= 2^{0}$	$(3, 1)$
4	2^{4-3} $= 2^{1}$	$(4, 2)$
5	2^{5-3} $= 2^{2}$	$(5, 4)$
6	2^{6-3} $= 2^{3}$	$(6, 8)$



The parent function of $g(x) = 2^{x-3}$ is $f(x) = 2^x$. Plot the points of the parent function on the same coordinate plane and compare them to $g(x)$. The points of $g(x)$ can be obtained by translating the points of $f(x)$ 3 units right.

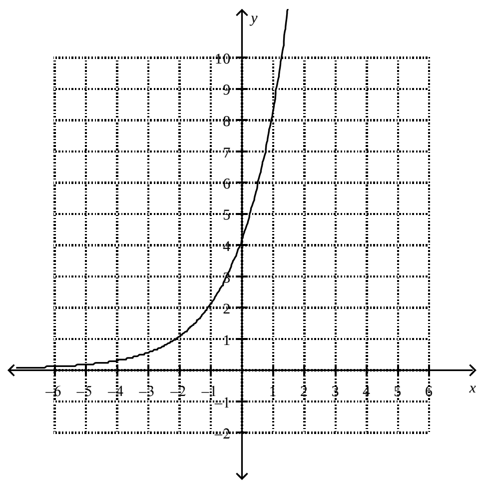
Discuss the key features of $g(x) = 2^{x-3}$: $g(x)$ is an exponential growth function whose

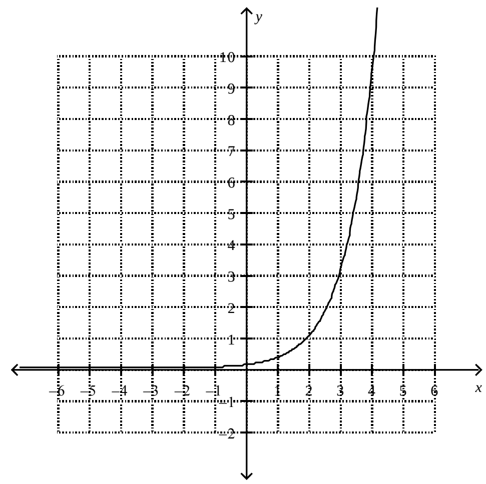
- domain is all real numbers
- range is all positive real numbers
- asymptote is $y = 0$ (there is no vertical shift)
- graph can be obtained by translating the graph of $f(x) = 2^x$ to the right 3 units.

<u>Try:</u> Choose a method and graph the functions.
Method #1- Use an input-output table.
Method #2- Translate the graph of the parent function.

Partner A: $g(x) = 2^{x+2}$ Partner B: $g(x) = 3^{x-2}$

Think-Pair: What kind of functions are they? Explain.
Identify the parent function.
How will you graph the functions?
Each partner graphs their function.
Partners exchange papers, graph their function on partner's paper. Compare and contrast.





Think-Pair-Share: In general, for $f(x) = a \cdot b^{x-h}$, which of the following are affected when $h \neq 0$?

<u>Domain:</u> [No] **<u>Range:</u>** [No] **<u>Intercept(s):</u>** [Yes] **<u>Asymptotes:</u>** [No]

Discuss:

- How does the value of *h* affect the graph of $f(x) = a \cdot b^{x-h}$?

  The value of *h* is the horizontal shift left or right of the parent function *h* units.

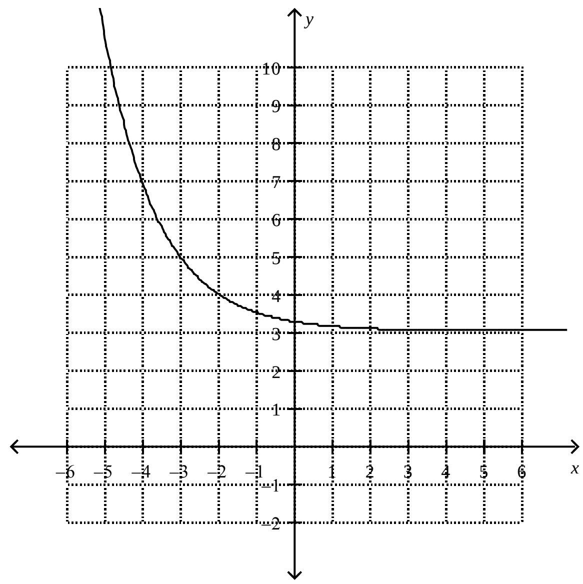
  If $h > 0$, then the graph shifts right *h* units. If $h < 0$, then the graph shifts left *h* units.

<u>Generalize:</u> To graph the exponential function $f(x) = b^{x-h} + k$, graph the parent function $f(x) = b^x$ and translate the graph horizontally *h* units and vertically *k* units.

Example 3: Graph the function $f(x)=\left(\frac{1}{2}\right)^{x+2}+3$:

Method 1: Make an input-output table. Start with the *x*-value that makes the exponent zero, then find at least two integer values less than and greater than your starting *x*-value.

x	$\left(\frac{1}{2}\right)^{x+2}+3$	$(x,\ f(x))$
-4	$\left(\frac{1}{2}\right)^{-4+2}+3$ $=\left(\frac{1}{2}\right)^{-2}+3$ $=4+3$	$(-4, 7)$
-3	$\left(\frac{1}{2}\right)^{-3+2}+3$ $=\left(\frac{1}{2}\right)^{-1}+3$ $=2+3$	$(-3, 5)$
-2 (Start)	$\left(\frac{1}{2}\right)^{-2+2}+3$ $=\left(\frac{1}{2}\right)^{0}+3$ $=1+3$	$(-2, 4)$
-1	$\left(\frac{1}{2}\right)^{-1+2}+3$ $=\left(\frac{1}{2}\right)^{1}+3$ $=\frac{1}{2}+3$	$\left(-1, 3\frac{1}{2}\right)$
0	$\left(\frac{1}{2}\right)^{0+2}+3$ $=\left(\frac{1}{2}\right)^{2}+3$ $=\frac{1}{4}+3$	$\left(0, 3\frac{1}{4}\right)$



Asymptote: $y=3$

Method 2: Translate the graph of the parent function.

a) Identify and find points on the parent function.

The parent function is $g(x)=\left(\frac{1}{2}\right)^{x}$.

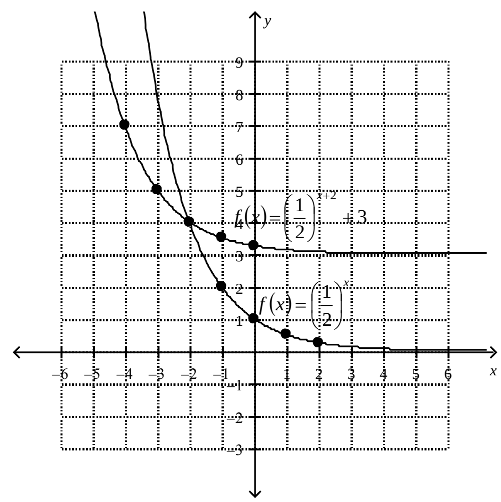
b) Identify the vertical and horizontal shift of the parent function.

Find h and k by comparing $f(x)=a\cdot b^{x-h}+k$ and $f(x)=\left(\frac{1}{2}\right)^{x+2}+3$.

Since $h=-2$, the horizontal shift is 2 units left and $k=3$, the vertical shift is 3 units up.

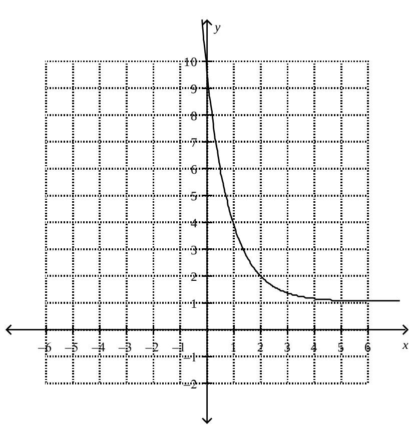
c) Graph $f(x)=\left(\frac{1}{2}\right)^{x+2}+3$ by translating the points of $f(x)=\left(\frac{1}{2}\right)^{x}$ 2 units left and 3 units up.

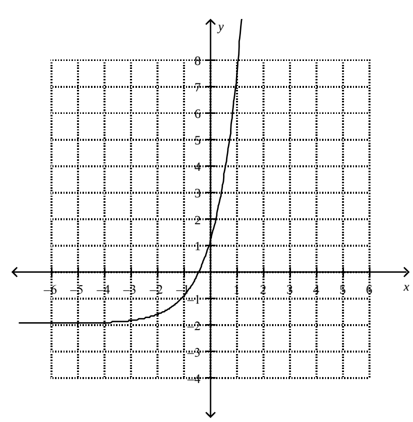
x	$\left(x, \left(\frac{1}{2}\right)^{x}\right)$	$\left(x-2, \left(\frac{1}{2}\right)^{x+2}+3\right)$	$f(x)=\left(\frac{1}{2}\right)^{x+2}+3$
-2	$(-2, 4)$	$(-2-2, 4+3)$	$(-4, 7)$
-1	$(-1, 2)$	$(-1-2, 2+3)$	$(-3, 5)$
0	$(0, 1)$	$(0-2, 1+3)$	$(-2, 4)$
1	$\left(1, \frac{1}{2}\right)$	$\left(1-2, \frac{1}{2}+3\right)$	$\left(-1, 3\frac{1}{2}\right)$
2	$\left(2, \frac{1}{4}\right)$	$\left(2-2, \frac{1}{4}+3\right)$	$\left(0, 3\frac{1}{4}\right)$



Try: Partner A: $f(x)=\left(\frac{1}{3}\right)^{x-2}+1$ Partner B: $f(x)=3^{x+1}-2$

Think-Pair: What kind of functions are they? Explain.
Identify the parent functions.
How will you graph the functions? Choose a method:
Method #1- Use an input-output table.
Method #2- Translate the graph of the parent function.
Each partner graphs their function.





<u>Exit Ticket 1:</u> Identify the key features of the graph of $f(x)=\left(\frac{1}{5}\right)^x$.

Domain:

Range:

Intercept(s):

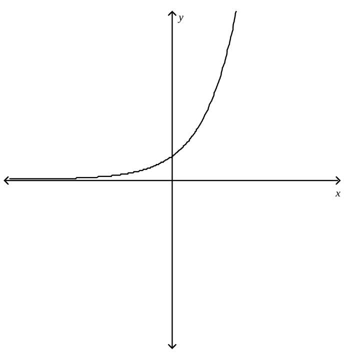
End Behavior:

Asymptote:

<u>Exit Ticket 2:</u> Match the functions to their graphs.

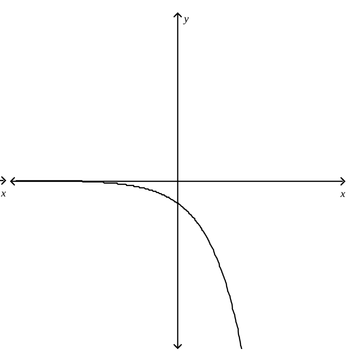
① $f(x)=-10\left(\frac{1}{6}\right)^x$ ② $f(x)=-\left(\frac{5}{4}\right)^x$ ③ $f(x)=9(4.5)^x$ ④ $f(x)=4\cdot\left(\frac{2}{3}\right)^x$

Graph A



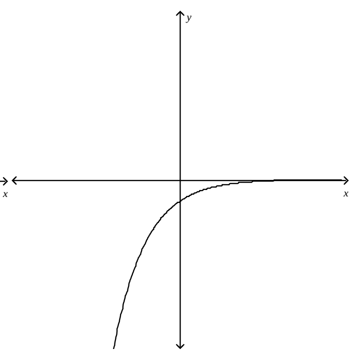
①②③④

Graph B



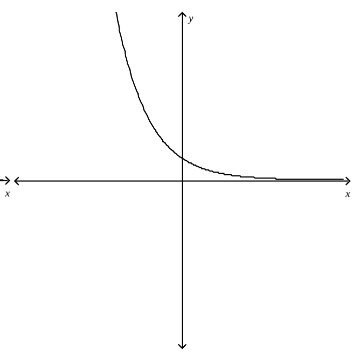
①②③④

Graph C



①②③④

Graph D

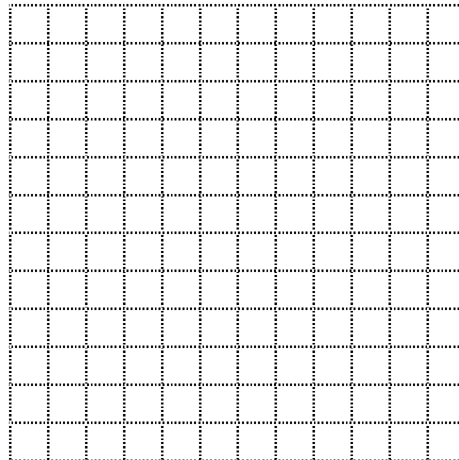


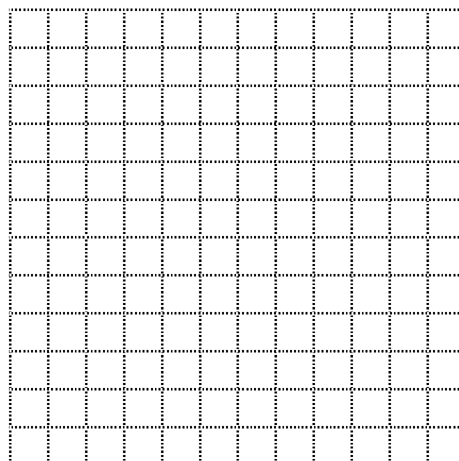
①②③④

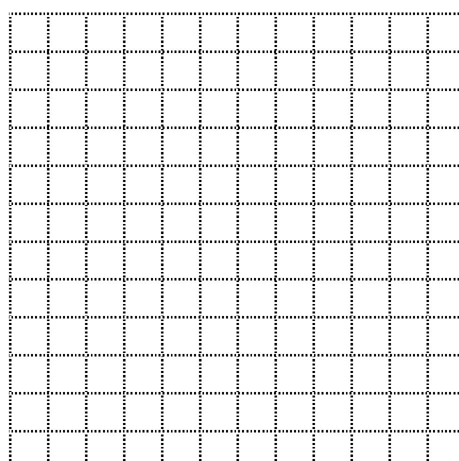
<u>Exit Ticket 3:</u> Determine if the function is an exponential growth or decay function. Identify the parent function, the horizontal shift and vertical shift of each function.

Function	Exponential Growth or Decay?	Parent Function	Horizontal Shift	Vertical Shift
$f(x)=10^{x-5}-4$				
$g(x)=4\left(\frac{1}{10}\right)^{x+5}$				

Graphing Exponential Functions (Day 3)







Warm-Up

CCSS: N-RN.2

Indicate if each expression is:

1 Between 0 and 1
2 Equal to 1
3 Greater than 1

A) $2^2 \cdot 2$ 1 2 3

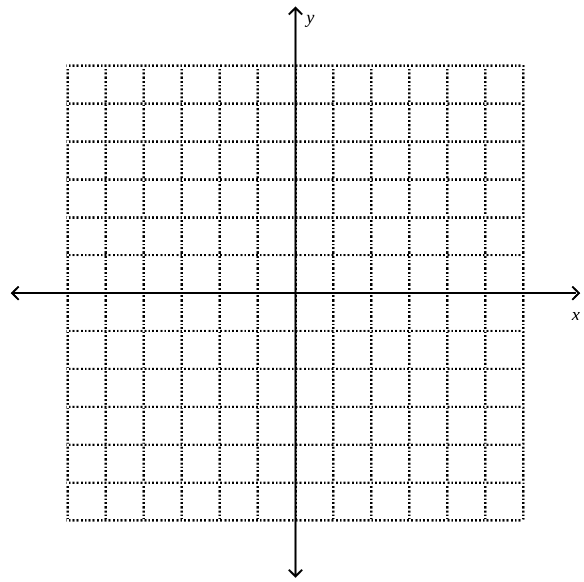
B) $\left(2^{-1}\right)^2$ 1 2 3

C) $\left(\frac{1}{2}\right)^{-1}$ 1 2 3

D) $\left(2^3\right)^2 \cdot 2^{-6}$ 1 2 3

CCSS: F-IF.7a:

Graph the function $f(x) = x^2 - 4$.



CCSS A-SSE.2:

Solve the equations by rewriting the right side of the equation as a power with the same base as the left side of the equation.

A) $3^{x+3} = 9$

B) $6^{x-5} = 1$

C) $\left(\frac{1}{2}\right)^{x} = 32$

CCSS F-IF.4:

Use the graph of the function $f(x) = x^2 - 4$ above to identify the key features.

a) Domain

b) Range

c) Intercept(s)

d) Maximum(s)/Minimum(s)

e) Intervals where the function is increasing and/or decreasing

c) Intervals where the function is positive and/or negative

Warm-Up Solutions

CCSS: N-RN.2

Indicate if each expression is:

① Between 0 and 1
② Equal to 1
③ Greater than 1

A) $2^2 \cdot 2$ ① ② ❸

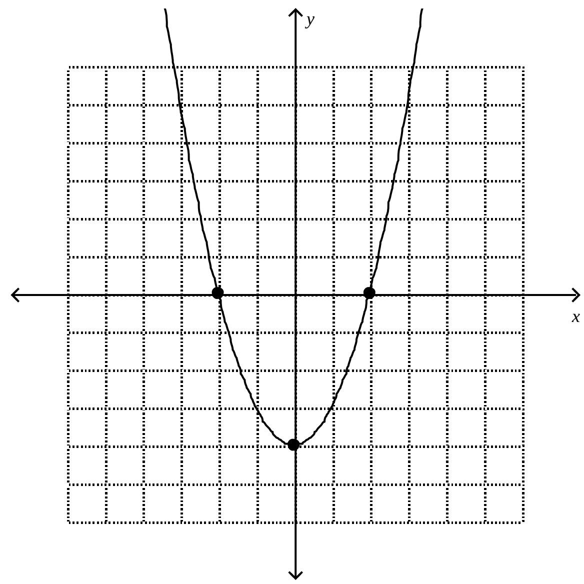
B) $\left(2^{-1}\right)^2$ ❶ ② ③

C) $\left(\frac{1}{2}\right)^{-1}$ ① ② ❸

D) $\left(2^3\right)^2 \cdot 2^{-6}$ ① ❷ ③

CCSS: F-IF.7a:

Graph the function $f(x)=x^2-4$.



CCSS A-SSE.2:

Solve the equations by rewriting the right side of the equation as a power with the same base as the left side of the equation.

A)
$$3^{x+3}=9$$
$$3^{x+3}=3^2$$
$$3^{x+3}=3^{-1+3}$$
$$x=-1$$

B)
$$6^{x-5}=1$$
$$6^{x-5}=6^0$$
$$6^{x-5}=6^{5-5}$$
$$x=5$$

C)
$$\left(\frac{1}{2}\right)^x=32$$
$$\left(\frac{1}{2}\right)^x=2^5$$
$$\left(\frac{1}{2}\right)^x=\left(\frac{1}{2}\right)^{-5}$$
$$x=-5$$

CCSS F-IF.4:

Use the graph of the function $f(x)=x^2-4$ above to identify the key features.

a) Domain: All real numbers x

b) Range: All real numbers $f(x)\geq -4$

c) Intercepts: $(0,-4)$, $(-2,0)$, $(2,0)$

d) The minimum occurs at $(0,-4)$ where the minimum value is -4.

e) The function is increasing for $x>0$.
The function is decreasing for $x<0$.

c) The function is positive for $x<-2$ and $x>2$.

The function is negative for $-2<x<2$.