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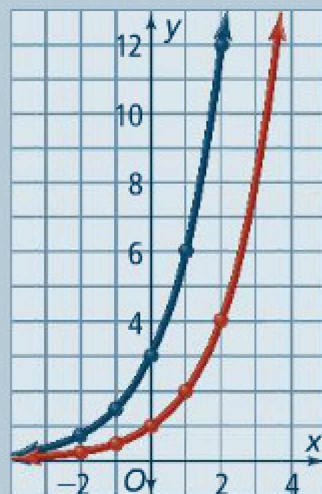
You can apply the four types of transformations—stretches, compressions, reflections, and translations—to exponential functions.

Essential Understanding The factor a in $y = ab^x$ can stretch or compress, and possibly reflect the graph of the parent function $y = b^x$.

The graphs of $y = 2^x$ (in red) and $y = 3 \cdot 2^x$ (in blue) are shown. Each y-value of $y = 3 \cdot 2^x$ is 3 times the corresponding y-value of the parent function $y = 2^x$.

x	$y = 2^x$	$y = 3 \cdot 2^x$
−2	$\frac{1}{4}$	$\frac{3}{4}$
−1	$\frac{1}{2}$	$\frac{3}{2}$
0	1	3
1	2	6
2	4	12



$y = 3 \cdot 2^x$ stretches the graph of the parent function $y = 2^x$ vertically by the factor 3.

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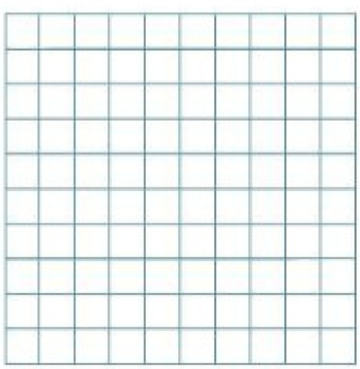
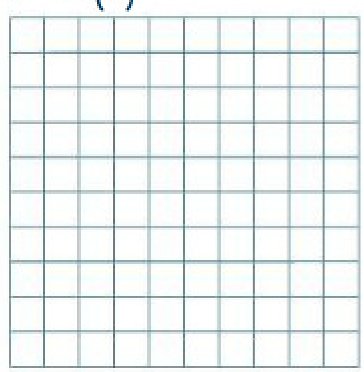
Problem 1 Graphing $y = ab^x$

Practice Graph each function. **State the domain and range.**

1. $y = -5^x$



2. $y = 24\left(\frac{1}{2}\right)^x$



A horizontal shift $y = ab^{(x-h)}$ is the same as the vertical stretch or compression $y = (ab^{-h})b^x$. A vertical shift $y = ab^x + k$ also shifts the horizontal asymptote from $y = 0$ to $y = k$.

Problem 2 Translating the Parent Function $y = b^x$

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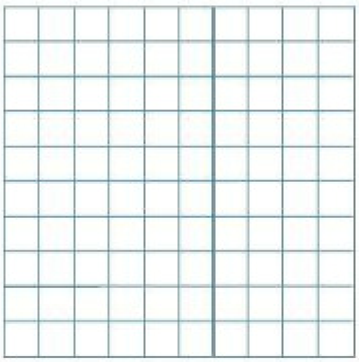
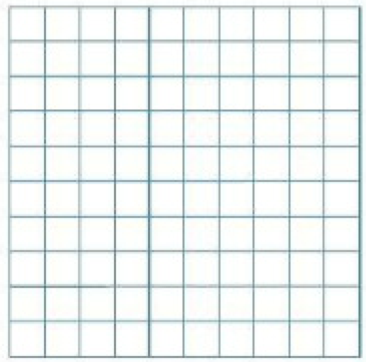
Practice **Graph each function as a transformation of its parent function. State the domain and range.**

3. $y = 3(2)^{x-1} + 4$



4. $y = -2(3)^{x+1} - 5$



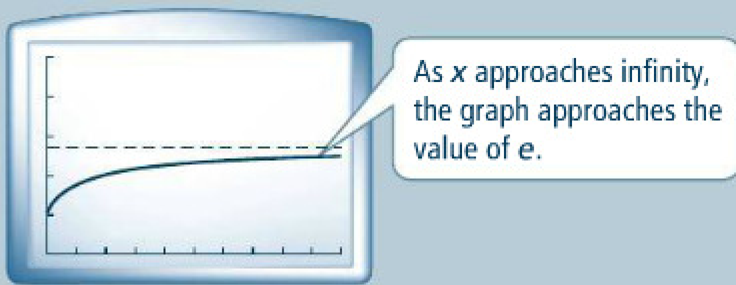
take note

Concept Summary Families of Exponential Functions

Parent function	$y = b^x$
Stretch ($\lvert a \rvert > 1$) Compression (Shrink) ($0 < \lvert a \rvert < 1$) Reflection ($a < 0$) in x-axis	$y = ab^x$
Translations (horizontal by h; vertical by k)	$y = b^{(x-h)} + k$
All transformations combined	$y = ab^{(x-h)} + k$

Up to this point you have worked with rational bases. However, exponential functions can have irrational bases as well. One important irrational base is the number e. The graph of $y = \left(1 + \frac{1}{x}\right)^x$ has an asymptote at $y = e$ or $y \approx 2.71828$.

x	$y = \left(1 + \frac{1}{x}\right)^x$
1	$y = 2$
10	$y \approx 2.594$
100	$y \approx 2.70$
1000	$y \approx 2.717$



Natural base exponential functions are exponential functions with base e. These functions are useful for describing continuous growth or decay. Exponential functions with base e have the same properties as other exponential functions.

Problem 5 Evaluating e^x

Practice **Graphing Calculator** Use the graph of $y = e^x$ to evaluate each expression to four decimal places.

8. e^6

9. e^e

The formula for continuously compounded interest uses the number e.

take note

Key Concept Continuously Compounded Interest

$$A(t) = P \cdot e^{rt}$$

- $A(t)$: amount in account at time t
- P: Principal
- r: interest rate (annual)
- t: time in years

Problem 6 Continuously Compounded Interest

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Practice Find the amount in a continuously compounded account for the given conditions.

10. principal: \$2000
annual interest rate: 5.1%
time: 3 years

11. principal: \$400
annual interest rate: 7.6%
time: 1.5 years