Section 4.5

Properties of Logarithms

OBJECTIVE 1

1 Work with the Properties of Logarithms

EXAMPLE

Establishing Properties of Logarithms

(a) Show that $\log_a 1 = 0$.

(b) Show that $\log_a a = 1$.

$$\log_a 1 = 0 \qquad \log_a a = 1$$

Properties of Logarithms

In the properties given next, M and a are positive real numbers, with $a \neq 1$, and r is any real number.

The number $\log_a M$ is the exponent to which a must be raised to obtain M.

$$a^{\log_a M} = M$$

The logarithm to the base a of a raised to a power equals that power.

$$\log_a a^r = r$$

EXAMPLE

Using Properties (1) and (2)

(a) $2^{\log_2 \pi} = \pi$ (b) $\log_{0.2} 0.2^{-\sqrt{2}} = -\sqrt{2}$ (c) $\ln e^{kt} = kt$

Properties of Logarithms

In the following properties, M, N, and a are positive real numbers, with $a \neq 1$, and r is any real number.

The Log of a Product Equals the Sum of the Logs

$$\log_a(MN) = \log_a M + \log_a N \tag{3}$$

The Log of a Quotient Equals the Difference of the Logs

$$\log_a\left(\frac{M}{N}\right) = \log_a M - \log_a N \tag{4}$$

The Log of a Power Equals the Product of the Power and the Log

$$\log_a M^r = r \log_a M \tag{5}$$

OBJECTIVE 2

2 **Write a Logarithmic Expression as a Sum or Difference of Logarithms**

EXAMPLE

Writing a Logarithmic Expression as a Sum of Logarithms

Write $\log_2\left(x^2\sqrt[3]{x-1}\right)$, $x>1$, as a sum of logarithms.

Express all powers as factors.

EXAMPLE

Writing a Logarithmic Expression as a Difference of Logarithms

Write $\log_6 \dfrac{x^4}{\left(x^2+3\right)^2}$, $x \neq 0$, as a difference of logarithms.

Express all powers as factors.

EXAMPLE

Writing a Logarithmic Expression as a Sum and Difference of Logarithms

Write $\ln \dfrac{x^3\sqrt{x-2}}{(x+1)^2}$, $x > 2$, as a sum and difference of logarithms.

Express all powers as factors.

OBJECTIVE 3

3 **Write a Logarithmic Expression as a Single Logarithm**

EXAMPLE

Writing Expressions as a Single Logarithm

Write each of the following as a single logarithm.

$$(a)\ 3\ln 2+\ln\left(x^2\right)+2$$

$$(b)\ \frac{1}{2}\log_a 4-2\log_a 5$$

$$(c)\ -2\log_a 3+3\log_a 2-\log_a\left(x^2+1\right)$$

Theorem

Properties of Logarithms

In the following properties, M, N, and a are positive real numbers, with $a \neq 1$.

If $M = N$, then $\log_a M = \log_a N$.

If $\log_a M = \log_a N$, then $M = N$.

OBJECTIVE 4

4 Evaluate Logarithms Whose Base Is Neither 10 nor e

EXAMPLE

Approximating Logarithms Whose Base Is Neither 10 nor e

Approximate $\log_3 12$. Round answer to four decimal places.

Theorem

Change-of-Base Formula

If $a \neq 1$, $b \neq 1$, and M are positive real numbers, then

$$\log_a M = \frac{\log_b M}{\log_b a}$$

$$\log_a M = \frac{\log M}{\log a} \quad \text{and} \quad \log_a M = \frac{\ln M}{\ln a}$$

EXAMPLE

Approximate: (a) $\log_5 89$ (b) $\log_{\sqrt{2}} \sqrt{5}$

Round answers to four decimal places.

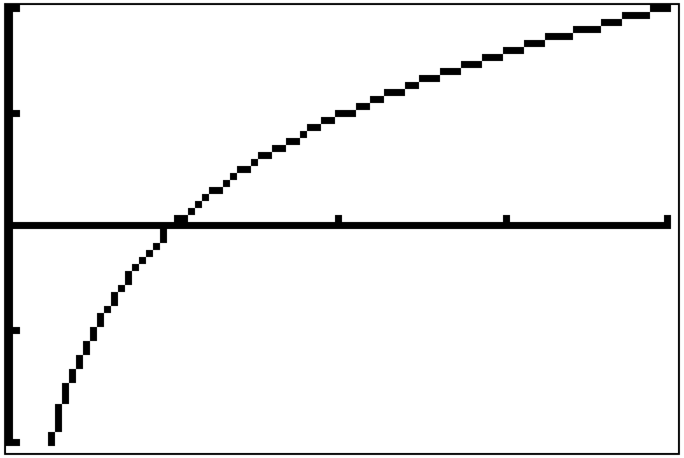
OBJECTIVE 5

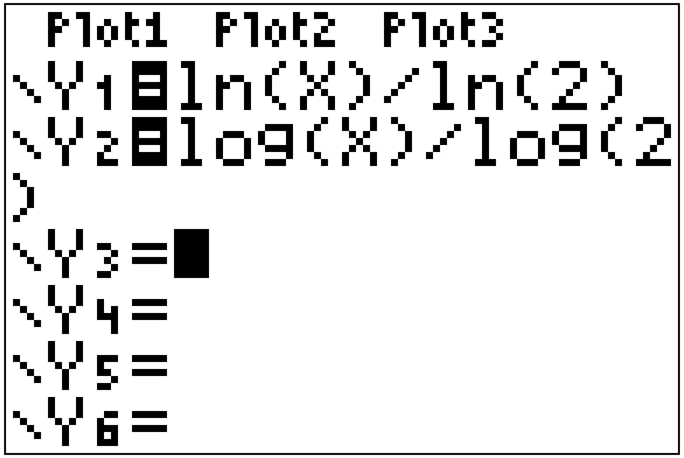
5 **Graph Logarithmic Functions Whose Base Is Neither 10 nor e**

EXAMPLE

Graphing a Logarithmic Function Whose Base Is Neither 10 nor e

Use a graphing utility to graph $y = \log_2 x$.





Summary

Properties of Logarithms

In the list that follows, $a > 0$, $a \neq 1$, and $b > 0$, $b \neq 1$; also, $M > 0$ and $N > 0$.

Definition $y = \log_a x$ means $x = a^y$

Properties of logarithms

$\log_a 1 = 0; \quad \log_a a = 1$

$a^{\log_a M} = M; \quad \log_a a^r = r$

$\log_a(MN) = \log_a M + \log_a N$

$\log_a\left(\frac{M}{N}\right) = \log_a M - \log_a N$

$\log_a M^r = r \log_a M$

If $M = N$, then $\log_a M = \log_a N$.

If $\log_a M = \log_a N$, then $M = N$.

Change-of-Base Formula $\log_a M = \frac{\log_b M}{\log_b a}$