

# Logarithmic Functions and Derivatives

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# Chapter 1

## 1.1 Derivatives of Logarithmic Functions

### Definition 1.1.1: Logarithmic Functions

Functions in the form:

$$y = \log_a[f(x)] \quad \text{or} \quad y = \ln[f(x)]$$

### 1.1.1 Derivate of $\ln(x)$

$$y' = \frac{f'(x)}{f(x)} \quad \text{or} \quad \frac{x'}{x}$$

Where  $y = \log_a[f(x)]$

$$y' = \frac{f'(x)}{x \ln(a)}$$

**Proof:**

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$

Where  $f(x) = \ln(x)$  and  $f(x+h) = \ln(x+h)$

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{\ln(x+h) - \ln(x)}{h}$$

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{\ln(x+h) - \ln(x)}{h}$$

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{\ln\left(\frac{x+h}{x}\right)}{h}$$

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{\ln\left(1 + \frac{h}{x}\right)}{h}$$

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{1}{h} \left( \ln\left(1 + \frac{h}{x}\right) \right)$$

Let  $v = \frac{h}{x} \quad \therefore h = vx \implies \text{As } h \rightarrow 0 \quad v \rightarrow 0$

$$\frac{dy}{dx} = \lim_{v \rightarrow 0} \frac{1}{vx} (\ln(1+v))$$

$$\frac{dy}{dx} = \lim_{v \rightarrow 0} \frac{1}{v} \times \frac{1}{x} \ln(1+v)$$

$$\frac{dy}{dx} = \frac{1}{x} \lim_{v \rightarrow 0} \frac{1}{v} \ln(1+v)$$

$$\frac{dy}{dx} = \frac{1}{x} \lim_{v \rightarrow 0} \ln(1+v)^{\frac{1}{v}}$$

$$\frac{dy}{dx} = \frac{1}{x} \ln[\lim_{v \rightarrow 0} (1+v)^{\frac{1}{v}}]$$

$$\frac{dy}{dx} = \frac{1}{x} \ln[e]$$

$$\frac{dy}{dx} = \frac{1}{x}$$



## Questions

### Question 1

$$y = 4^x - 5 \log_7 x$$

*Solution:*

$$y' = 4^x \ln(4) - \frac{5}{\ln(7)x}$$

### Question 2

$$f(t) = 4 \log_3(t) - \ln(t)$$

*Solution:*

$$f'(t) = \frac{4}{\ln(3)t} - \frac{1}{t}$$

### Question 3

$$y = 3^x \log(x)$$

*Solution:*

$$y' = (3^x \ln(3))(\log(x)) + (3^x)\left(\frac{1}{\ln(10)x}\right)$$

$$y' = 3^x \ln(3) \log(x) + \frac{3^x}{\ln(10)x}$$