

# Data Science Math Skills

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# Data Science Math Skills

## Course Information

Data Science Math Skills by **Duke University** is a online course you can take on this site [Coursera](#).

## Motivation for Learning & Re-learning

A lot of graduate school students struggle with Data Science courses only because of their lack of knowledge and/or understanding of Mathematics for Data Science. The course gives an overview of Mathematical concepts you will encounter while learning Data Science.

## Supplemental Notes and Videos

Here's how I make my notes:

My notes include videos from Khan Academy and other websites. The content's the same, and often a bit better due to lack of errors. The text are usually from the Coursera video transcripts.

I indicate **why** it is important to learn such concepts through **Further Reading** notes.

## Sets and What They're Good For

### Set Basics and Vocabulary

- [Set Theory](#)
- [Set Theory Operations](#)

### Further Reading

A set is the fundamental discrete structure on which all other discrete structures are built.

Those who studied Discrete Mathematics or read a book about it will probably just re-learn a lot from this course on Set Basics.

- [Applications of Set Theory in Computer Science](#) - A list of the most obvious applications of Set Theory.
- [Discrete Mathematics and Its Applications](#) - I read most of the book as a supplemental material for a Discrete Math course. The book clearly states why a set is the foundational structure in Computer Science.

### Venn Diagrams

- [What are Venn diagrams?](#)

### Further Reading

- [A Visual Explanation of SQL Joins](#)

## The Infinite World of Real Numbers

- [What are Real Numbers?](#)
- [Multi-step Inequalities](#)

## The Jagged S Symbol

- [Sigma/Summation Notation](#)

$$\sum_{n=1}^{10} n^2$$

- The Sigma has similarities to the [factorial](#) symbol, but it suggests that you add the values of  $i$  based on the stopping point  $n$

## Further Reading

- [Graph-based Machine Learning](#)

## Descartes Was Really Smart

### Plotting Points

- The x-axis is going to be the set of all points x-y in the Cartesian plane, x-y in  $\mathbb{R}^2$ , such that their y coordinate is zero.
- We divide the Cartesian plane into four separate regions, and these we call **quadrants**.
- [Coordinate plane: quadrants](#)

### Distance Formula

- [Distance formula](#)

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

### Point-Slope Formula for Lines

- [Point Slope Form](#)

$$y - b = m(x - a)$$

- [Calculating the Slope](#)

$$(y_2 - y_1 / x_2 - x_1)$$

### Slope-Intercept Formula

- [Slope Intercept Equation](#)
- [Intro to Slope Intercept Form](#)

$$y = mx + b$$

## Input-Output Machines

### Functions: Mapping from Sets to Sets

- [Functions on Sets - UCLA](#)

$$f : A \rightarrow B$$

### Functions: Graphing in the Cartesian Plane

- [Functions on a Coordinate Plane](#)
- [Vertical line test](#)
- The **vertical line** test says: *any vertical line, intersects the graph of a function once*. If it intersects it more than once, we violate things here.

### Increasing and Decreasing Functions

- A function is increasing whenever:  
 $a < b$   
 $f(a) < f(b)$   
 $f(x) = 2^x$  – An example of an increasing function
- A function is decreasing whenever:  
 $a > b$   
 $f(a) > f(b)$   
 $g(x) = 3^{-x}$  – An example of a decreasing function

### Composition and Inverse

- [How to find the inverse of a composite function](#)
- [Evaluating Composite functions](#)
- Not every function has an inverse.
- If the graph of  $f$  fails the *horizontal line test*, the graph has no inverse.

## This is about that derivative stuff

### Tangent Lines - Slope of a Graph at a Point

- [How to find the slope & equation of tangent line at a given point](#)
- [Finding the Equation Of A Tangent Line](#)
- A **Tangent Line** is a line which locally touches a curve at one and only one point.
- Formulas:  
 $f'(a)$

## Tangent Lines - The Derivative Function

- [The derivative & tangent line equations](#)
- Formulas:

$$f'(x) = 2x$$

$$f(x) = x^2$$

## Fast Growth, Slow Growth

### Using Integer Exponents

- 0 as an exponent:  
 $2^0 = 1$
- Negative exponents:  
 $x^{-n} = 1/x^n$
- [Scientific Notation](#)

### Simplification Rules for Algebra using Exponents

- Multiplication rule  
 $x^n x^m = x^{(n+m)}$
- Power to a power  
 $(x^n)^m = x^{nm}$
- Product to a power  
 $(xy)^n = x^n y^n$
- Fraction to a power  
 $\frac{x^n}{y} = \frac{x^n}{y^1}$
- Division and negative powers  
 $\frac{x^n}{x^m} = x^{n-m}$
- Fractional exponents  
 $x^{(\frac{a}{b})} = \sqrt[b]{x^a}$

### How Logarithms & Exponents are Related

- [Intro to logarithms](#)
- Exponential form:  
 $b^x = N$
- Logarithmic form:  
 $x = \log_b N$
- The logarithm of any base of 1 is 0, just as any number raised to 0 is 1.

- [Solving Logarithmic Equations](#): This video was more helpful in understanding how to solve for  $x$  on a Logarithmic equation problem.

### General rules

- Product rule  

$$\log(xy) = \log(x) + \log(y)$$
- Quotient rule  

$$\log\frac{x}{y} = \log(x) - \log(y)$$
- Power and root rule  

$$\log(x^n) = n\log(x)$$

### Further Reading

- One of the most popular concepts in Data Science is in its logarithmic form ( $\ln$ ): [Logistic Regression](#)
- Watch more about [Simple Logistic Regression](#)

### Change of Base

- The base of **10**, **2** and the natural log ( $e$ ) are common in Data Science.
- Formula for changing the base:

$$\log_a(b) = \frac{\log_x(b)}{\log_x(a)}$$

### The Rate of Growth of Continuous Processes

- Exponential rate of growth can be a **discrete** exponential rate of growth or a **continuous** exponential rate of growth.
- Note: those who studied Finance will likely see the practicality of knowing, but not of the terms of themselves.
- Discrete rate of growth:  

$$1.00(1 + r)^t$$
- [Euler's constant  \$e\$](#)
- What is  $e$ ?  

$$2.71828$$
- Euler is pronounced *Oyler*. He's a mathematician most famously known of his solution to the graph theory problem: [Seven Bridges of Königsberg](#)
- Problem: A baby elephant weighing 200 kg grows at a continuously compounded rate of 5%/year. How much does it weigh in 3 years?  

$$(200\text{kg})e^{(0.05)(3)} = 232.4\text{kg}$$

## Basic Probability Definitions

### Probability Definitions and Notation

#### Definition

- Probability is the degree of belief in the truth or falsity of a statement.
- When I am certain that a statement is true then that statement is assigned probability **1** and if I'm certain the statement is false, then it's assigned probability is **0**.

#### Notation

- The probability of  $x$ :

$$P(x)$$

- The negation of statement  $x$ :

$$\neg x$$

#### Law of excluded middle

- Probability of a statement and the probability of the negation of a statement must sum to 1.

$$P(x) + P(\neg x) = 1$$

#### Principle of indifference

- For the  $i$ -th outcome  $x_i$  in a distribution with  $n$  possible outcomes.

$$P_{xi} = \frac{1}{n}$$

$$P(\text{event}) = \frac{\text{number of outcomes as defined in event}}{\text{total number of possible outcomes in universe}}$$

## Permutations and Combinations

### Permutations

- Order matters
- Example:  
placing five people in five different positions: 120 ways

- [Permutations](#)

- Formula:

$$\frac{n!}{(n-m)!}$$

### Combinations

- Order does not matter
- Example:  
forming a five-person team from five people: 1

- [Combinations](#)

- Formula:

$$\frac{n!}{r!(n-r)!}$$

### Replacement

- Sampling *with replacement* (independent), e.g. drawing a card and putting it back in the deck
- Sampling *without replacement*, e.g. drawing a card from a deck and not putting it back

### Using Factorial and “M choose N”

#### Factorial

- A factorial is the operation where we take a number and multiply it by each integer that is 1 less until we get down to 1.

#### “m choose n”

- Draw  $n$  items from a group of  $m$  items without replacement.

$$\binom{m}{n} = \frac{m!}{(m-n)!n!}$$

### Further Reading

- This is a recap of Discrete Mathematics. Try to read [Discrete Mathematics and Its Applications](#).