

The binomial theorem

Introduction to Engineering Mathematics

Prof. Joris Vankerschaver

Overview

- Pascal's triangle
- Binomial coefficients
- Binomial theorem

Pascal's triangle

Expand the following expressions and look at the coefficients.

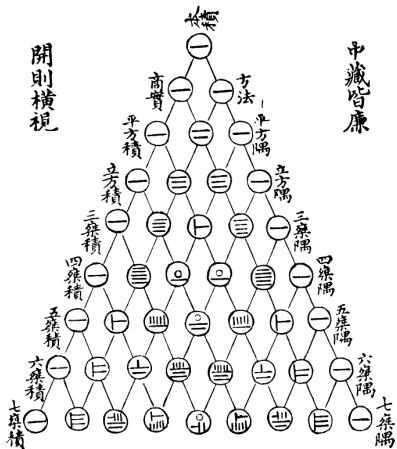
- $(a + b)^0 = 1$
- $(a + b)^1 = a + b$
- $(a + b)^2 = a^2 + 2ab + b^2$
- $(a + b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$
- $(a + b)^4 = a^4 + 4a^3b + 6a^2b^2 + 4ab^3 + b^4$
- $(a + b)^5 = a^5 + 5a^4b + 10a^3b^2 + 10a^2b^3 + 5ab^4 + b^5$

What do you notice?

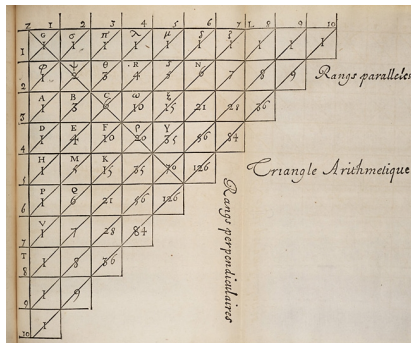
Based on this pattern, what is $(a + b)^7$?

Would you be able to write down $(a + b)^{27}$?

古法七乘方圖



| | | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|
| 七乘積 | 六乘積 | 五乘積 | 四乘積 | 三乘積 | 二乘積 | 一乘積 | 方積 | 方隅 | 七乘方 | 六乘方 | 五乘方 | 四乘方 | 三乘方 | 二乘方 | 一乘方 | 七乘方 |
|-----|-----|-----|-----|-----|-----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|



Blaise Pascal, 1665 CE

Example

Use Pascal's triangle to expand $\left(2x + \frac{1}{x}\right)^5$.

Binomial coefficients

- Factorial: $n! = n(n-1)(n-2) \cdots 2 \cdot 1$.
- Binomial coefficient (also called “n-choose-k”):

$$\binom{n}{k} = C_n^k = \frac{n!}{k!(n-k)!}.$$

- Measures the number of ways of choosing k objects from among n choices.

Properties

For all n and $k \leq n$:

$$\binom{n}{0} = \binom{n}{n} = 1$$

$$\binom{n}{1} = \binom{n}{n-1} = n$$

$$\binom{n}{k} = \binom{n}{n-k}$$

Rewriting Pascal's triangle using binomial coefficients

The binomial expansion

Putting everything we've learned together, we get

$$(a+b)^n = \binom{n}{0}a^n b^0 + \binom{n}{1}a^{n-1}b^1 + \cdots + \binom{n}{n-1}a^1 b^{n-1} + \binom{n}{n}a^0 b^n.$$

This can be written more compactly as

$$(a+b)^n = \sum_{k=0}^n \binom{n}{k} a^{n-k} b^k.$$


Example

Use the binomial expansion to expand $(\sqrt{x} - 1)^7$.

Visual proof of the binomial expansion (optional)

$$(a+b)^1 = \underline{a} + \underline{b}$$

$$(a+b)^2 = a^2 + 2ab + b^2$$


$$(a+b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$$


$$(a+b)^4 = a^4 + 4a^3b + 6a^2b^2 + 4ab^3 + b^4$$
