α β γ δ ε ζ
η θ ι κ λ μ
ν ξ ο π ρ σ
τ υ φ χ ψ ω

Reading the Greek

A Letter-by-Letter Guide to the Symbols of Science and Finance

for Anyone Who Ever Got Lost in an Equation

Probal Bose

Σ σ

A free sample of *Reading the Greek*

This sample has 2 parts of the book. First comes **The Alphabet at a Glance**, all 24 letters with how to say them and how to type them. Then comes the complete chapter on **sigma**, one of the busiest letters in science and finance.

Every chapter in the book has the same shape. It opens with how to say, type and write the letter, and the symbols it's most often confused with. A short history follows, from Phoenician to Latin and Cyrillic. Then colour-coded cards take the letter field by field, each with a plain English line, the formula, a note on every symbol in it and, for most, a diagram.

Maths **Physics** **Stats** **Finance**

Chapters end with traps to avoid, a short Python program to try, and a few questions to check yourself. The answers are at the back of the book.

The Alphabet at a Glance

	Letters	Name	Say it	LaTeX
1	$\mathrm{A}\ \alpha$	alpha	AL-fuh	`\alpha`
2	$\mathrm{B}\ \beta$ (ϐ)	beta	BEE-tuh (UK), BAY-tuh (US)	`\beta`
3	$\Gamma\ \gamma$	gamma	GAM-uh	`\gamma`
4	$\Delta\ \delta$	delta	DEL-tuh	`\delta`
5	$\mathrm{E}\ \varepsilon$ (ϵ)	epsilon	EP-sih-lon	`\varepsilon`, `\epsilon`
6	$\mathrm{Z}\ \zeta$	zeta	ZEE-tuh (UK), ZAY-tuh (US)	`\zeta`
7	$\mathrm{H}\ \eta$	eta	EE-tuh (UK), AY-tuh (US)	`\eta`
8	$\Theta\ \theta$ (ϑ)	theta	THEE-tuh (UK), THAY-tuh (US)	`\theta`, `\vartheta`
9	$\mathrm{I}\ \iota$	iota	eye-OH-tuh	`\iota`
10	$\mathrm{K}\ \kappa$ ($\varkappa$)	kappa	KAP-uh	`\kappa`
11	$\Lambda\ \lambda$	lambda	LAM-duh	`\lambda`
12	$\mathrm{M}\ \mu$	mu	MYOO	`\mu`
13	$\mathrm{N}\ \nu$	nu	NYOO	`\nu`
14	$\Xi\ \xi$	xi	KSY, ZY or KSEE	`\xi`
15	$\mathrm{O}\ o$	omicron	OH-mih-kron	`o`
16	$\Pi\ \pi$ (ϖ)	pi	PIE	`\pi`, `\varpi`
17	$\mathrm{P}\ \rho$ (ϱ)	rho	ROH	`\rho`, `\varrho`
18	$\Sigma\ \sigma$ (ς)	sigma	SIG-muh	`\sigma`, `\varsigma`
19	$\mathrm{T}\ \tau$	tau	TOW (rhymes with *cow*) or TAW	`\tau`
20	$\Upsilon\ \upsilon$ (ϒ)	upsilon	UP-sih-lon or OOP-sih-lon	`\upsilon`
21	$\Phi\ \varphi$ (ϕ)	phi	FIE (UK), FEE (US)	`\varphi`, `\phi`
22	$\mathrm{X}\ \chi$	chi	KIE (rhymes with *sky*)	`\chi`
23	$\Psi\ \psi$	psi	(P)SIE	`\psi`
24	$\Omega\ \omega$	omega	OH-mih-guh	`\omega`

Variant forms are shown in brackets. Capitals that look identical to Latin letters (A, B, E, Z, H, I, K, M, N, O, P, T, X) have no LaTeX command of their own, so you simply type the Latin letter.

The pronunciations are the ones you'll hear in lecture halls where English is spoken, and they vary. Modern Greek pronounces many letters differently. For example, *beta* is *VEE-ta*, *delta* is *THEL-ta* with a soft *th*, and *chi* is a throaty *hee*. Nobody will mind which you use, as long as you're consistent.

18 Sigma

Σ σ ς

SAY	SIG-muh
TYPE	`\sigma`
CODE	U+03C3
WRITE	*a small o with a flat stroke off the top right*

DON'T CONFUSE WITH

- ∑ summation sign
- 6 the digit 6
- E Latin E

The big idea: capital Σ means **add them all up**. Small σ means **spread**, or how far values typically stray from the average. In finance that spread is called *volatility*, and it's probably the single most used number in the whole of risk management.

Where it came from

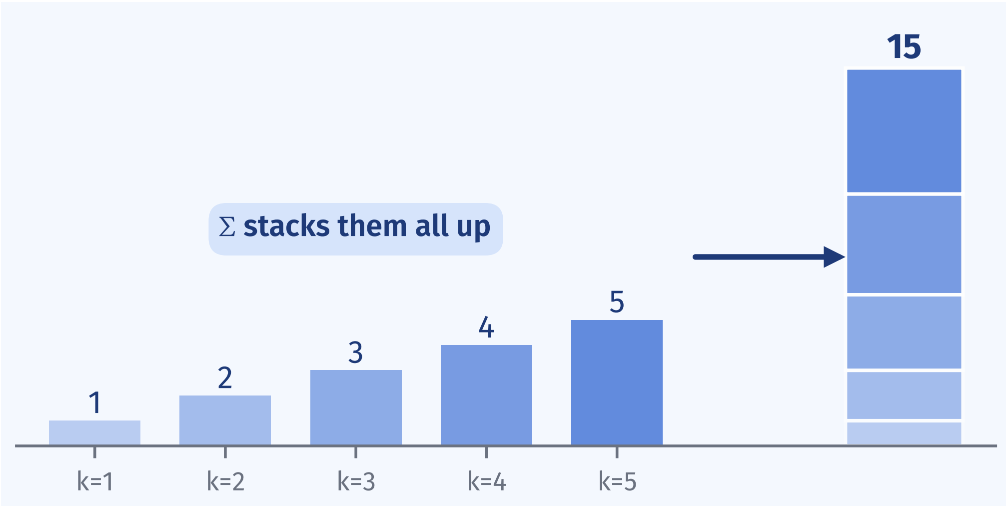
PHOENICIAN		GREEK		LATIN		CYRILLIC
𐤔	→	Σ σ ς	→	S s	→	С с
shin 'tooth', ~1050 BCE		sigma, ~800 BCE		Roman S		from the round sigma c

Sigma descends from the Phoenician *shin*, "tooth", drawn as a row of zigzag teeth (Healey 1990). Turned on its side, the zigzag became Σ, which kept the /s/ sound and served as the numeral 200. Greek writes small sigma 2 ways, σ inside a word and ς at the end of one, as in the word *logos*. In later Greek handwriting a rounded, C-shaped form (**c**) was common, and it's this *lunate* sigma that became Cyrillic **С**. Latin **S** is a rounded, turned version of the earlier shape.

Maths

Capital Σ is **the summation sign**, a compact instruction to add up a list of terms. Leonhard Euler introduced it in 1755, and it's now one of the most recognisable symbols in mathematics (Cajori 1928–1929). Small σ has more specialised jobs, such as the σ-*algebra* at the foundation of probability theory.

MATHS The summation sign



Add up a whole list of terms.

$$\sum_{k=1}^{n} a_k = a_1 + a_2 + \cdots + a_n, \qquad \sum_{k=1}^{5} k = 15$$

WHERE

$\sum$ capital sigma, "add all of these"

k the *index*, a counter that runs through the whole numbers

$k = 1$ where the counter starts; it stops at n

a_k the term being added for each value of k

GOING DEEPER

Σ is the adding cousin of Π (multiplying, Chapter 16). An integral $\int$ is the continuous version of Σ, and its elongated S literally stands for *summa*. The young Gauss is said to have added 1 to 100 in seconds by pairing terms, giving 100 × 101 / 2 = 5,050.

MATHS Sigma-algebras

The collection of events you're allowed to assign probabilities to.

$\mathscr{F}$ is a σ-algebra on Ω

WHERE

- Ω the set of all possible outcomes (Chapter 24)
- $\mathscr{F}$ a family of subsets of Ω, the "events"
- σ the prefix, meaning closed under combining *countably many* events, so infinite sequences are allowed

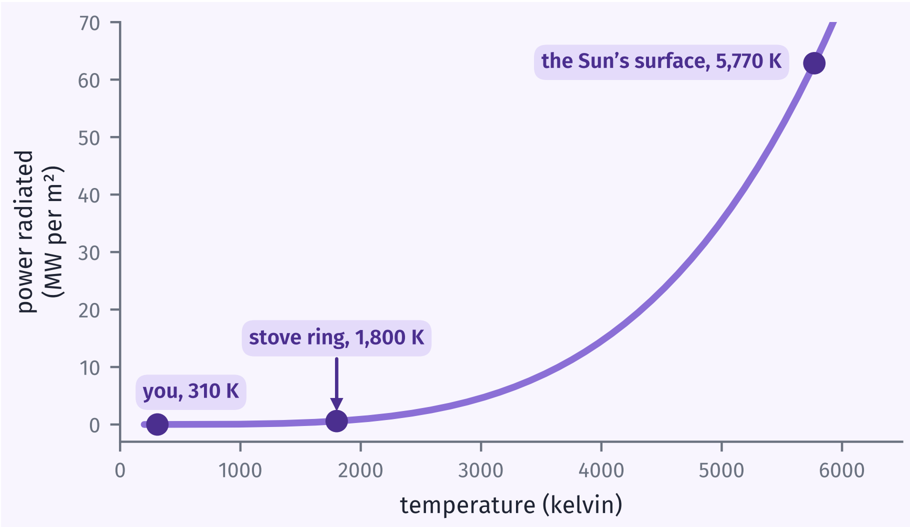
GOING DEEPER

Kolmogorov made σ-algebras the technical backbone of modern probability in 1933. In finance, a growing sequence of σ-algebras, called a *filtration*, models the information available to traders as time passes.

Physics

Several physics quantities share the letter σ, and most of them have a common flavour, **something to do with area**. The Stefan–Boltzmann constant σ sets the heat that each square metre of a hot surface radiates. *Stress* σ is force per unit area inside a material. Electrical *conductivity* σ is the reciprocal of resistivity ρ (Chapter 17). Particle physicists also use σ for a *cross-section*, the effective target area a particle presents.

PHYSICS The Stefan–Boltzmann law



Hot objects glow, and the power they radiate rises very steeply with temperature.

$$P = \varepsilon \sigma A T^4$$

WHERE

- P the power radiated, in watts
- A the surface area
- T the absolute temperature, in kelvin
- σ the Stefan–Boltzmann constant, 5.67×10^{-8} W/m²K⁴
- ε the emissivity, 1 for a perfect radiator (Chapter 5)

GOING DEEPER

Because of the T^4, doubling the temperature multiplies the radiated power by 16. The Sun's surface, at about 5,770 K, radiates some 60 megawatts from every square metre.

PHYSICS Stress

σ

The force inside a material, spread over its cross-section.

$$\sigma = \frac{F}{A}$$

WHERE

- F the force pulling or pushing on the material
- A the cross-sectional area carrying it
- σ the stress, in pascals (newtons per square metre)

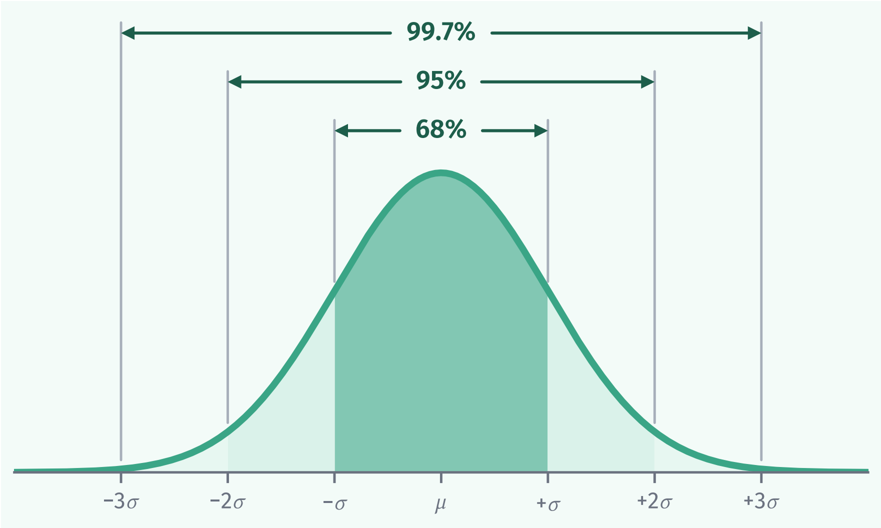
GOING DEEPER

Stress causes strain (ε, Chapter 5), and for many materials σ = E ε, where E is the stiffness (Young's modulus). Engineers keep σ well below the material's breaking stress.

Stats

In statistics, small σ is **the standard deviation**, the typical distance of values from their mean. Its square, σ^2, is the *variance*. Capital Σ, bold or plain, commonly names a **covariance matrix**, which records the spreads of several quantities and how they move together. As with μ (Chapter 12), Greek σ is the true population value; the sample estimate is written s.

STATS The standard deviation



How spread out values are around their average.

$$\sigma = \sqrt{\mathrm{E}\big[(X-\mu)^2\big]}$$

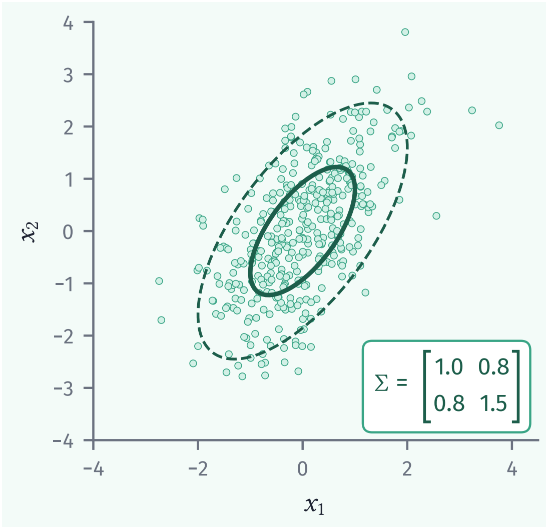
WHERE

X	the random quantity
μ	its mean
$(X-\mu)^2$	the squared distance from the mean
$\mathrm{E}[\ldots]$	the average of that; its square root is σ

GOING DEEPER

For a bell shaped (normal) distribution, about 68% of values lie within 1σ of the mean, 95% within 2σ and 99.7% within 3σ. Karl Pearson named it the standard deviation and wrote it σ (Pearson 1894). “Six sigma” in manufacturing means making defects astonishingly rare.

STATS The covariance matrix



A table of spreads and co-movements for several quantities at once.

$$\Sigma = \begin{pmatrix} \sigma_1^2 & \rho\,\sigma_1\sigma_2 \\ \rho\,\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}$$

WHERE

σ_1^2, σ_2^2	the variances of the 2 quantities, on the diagonal
$\rho\,\sigma_1\sigma_2$	their covariance, off the diagonal (ρ is the correlation, Chapter 17)
Σ	the whole matrix

GOING DEEPER

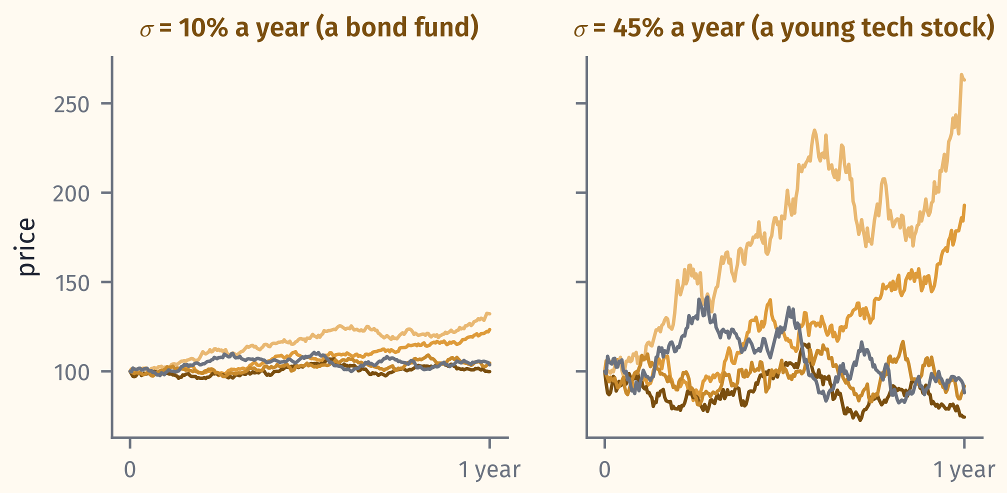
Drawn as ellipses, Σ shows the shape of a cloud of data, with its tilt set by ρ and its width by the σ's. Portfolio risk is calculated from Σ, so estimating it well is a big deal in finance.

σ

Finance

Finance calls σ **volatility**, the standard deviation of returns, normally quoted per year. It's the default measure of risk. It drives option prices (Black–Scholes has σ at its heart), sets position sizes and risk limits, and appears in the famous Sharpe ratio. When traders say "vol", they mean σ.

FINANCE Volatility



The typical yearly swing in an investment's returns.

$$\sigma_{\text{year}} = \sigma_{\text{day}} \times \sqrt{252}$$

WHERE

σ_{day}	the standard deviation of daily returns
252	roughly the number of trading days in a year
σ_{year}	the annualised volatility, e.g. about 15–20% for a broad stock index

GOING DEEPER

Risk grows with the *square root* of time, not with time, because random ups and downs partly cancel. A 1.2% daily volatility is about 19% a year. *Implied volatility* is the σ that makes the Black–Scholes formula match an option's market price (Black and Scholes 1973).

σ

FINANCE **The Sharpe ratio**

Reward per unit of risk.

$$S = \frac{\mu - r_f}{\sigma}$$

WHERE

μ	the investment's expected return
r_f	the risk-free rate
σ	its volatility
S	the Sharpe ratio; above 1 is considered very good for a whole strategy

GOING DEEPER

Proposed by William Sharpe in 1966 (Sharpe 1966), it lets you compare a calm investment with a wild one on equal terms. It treats upside and downside swings alike, which is its main weakness.

TRAPS **Don't get caught out**

- Σ **vs** $\sum$**.** The letter Σ is a *matrix* or a name; the larger $\sum$ is the summation sign. Context generally tells them apart, since $\sum$ has limits above and below it.
- σ **vs** σ^2**.** Volatility is σ; variance is σ^2. Mixing them up squares your error.
- σ **vs s.** σ is the population value; s is the estimate from a sample, which divides by n − 1.
- **Annualising.** Multiply daily σ by $\sqrt{252}$, not by 252.

σ

CODE **Try it**

Compute daily and annual volatility, and check the 68–95–99.7 rule. Needs NumPy.

```python
import numpy as np

rng = np.random.default_rng(3)
daily = rng.normal(0.0003, 0.012, 2_520)       # 10 years of daily returns

sigma_daily = daily.std(ddof=1)               # standard deviation of a single day
sigma_year = sigma_daily * np.sqrt(252)        # about 252 trading days a year
print(f"daily volatility:  {sigma_daily:.2%}")
print(f"annual volatility: {sigma_year:.1%}")

# The 68-95-99.7 rule, checked on the simulated data
z = (daily - daily.mean()) / sigma_daily
for k in (1, 2, 3):
    print(f"within {k} sigma: {np.mean(np.abs(z) <= k):.1%}")
```

OUTPUT

```
daily volatility:  1.20%
annual volatility: 19.0%
within 1 sigma: 68.5%
within 2 sigma: 95.4%
within 3 sigma: 99.7%
```

QUIZ **Check yourself**

1. When does Greek write small sigma as σ, and when as ς?
2. What is $\sum_{k=1}^{4} k^2$?
3. Test scores have μ = 70 and σ = 10 and are bell shaped. What share of students score between 50 and 90?
4. A stock's daily volatility is 2%. Roughly what is its annual volatility?
5. Fund A returns 8% with σ = 10%; fund B returns 12% with σ = 25%. With r_f = 2%, which has the higher Sharpe ratio?

σ

A … Ω

Enjoyed sigma? There are 23 more letters.

Reading the Greek: A Letter-by-Letter Guide to the Symbols of Science and Finance, for Anyone Who Ever Got Lost in an Equation covers the whole alphabet, from α to ω, in 224 full colour pages, with a symbol finder for each field at the back.

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