Imperial Algorithmic Trading Society

Week 2: Creating and assessing trading algorithms

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Course Syllabus

L1 – Introduction and the basics of algorithmic trading

L2 – Creating and assessing trading algorithms

L3 – Portfolio Optimisation

L4 – External industry lecture

L5 – Machine learning in algorithmic trading

L6 – Options

L7 – External Industry lecture

L8 – The role of impact

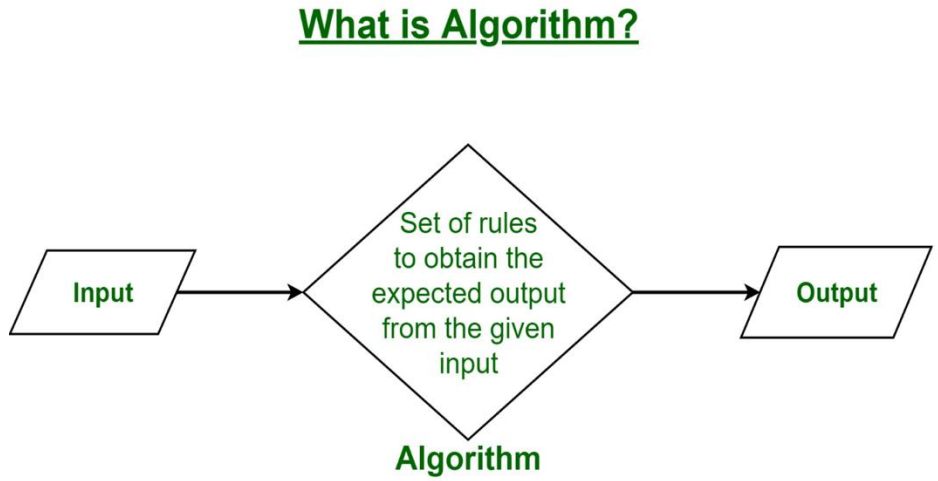
Trading Algorithms

What do we mean by a trading ‘algorithm’?

Trading algorithms simply defined

- At the lowest level, trading algos are a **set of instructions** (in code) that **automate** the process of buying and selling financial assets

- When preset conditions are met, algos generate **signals** to buy or sell



The workflow of a trading algorithm

The workflow of a trading algorithm

What is a trading signal?

Trading signal

‘An indicator/trigger for action to buy or sell a security, generated through analysis’

The strategies we will be covering

- Moving average/momentum
- Mean reversion
- Pairs trading

Moving average/momentum

Initial guesses?

Moving average/momentum

Using **moving averages (MA)** to identify the direction / **momentum** of a stock

Involves taking the **average stock price** over 2 periods: a **fast and slow** period

- Common to measure a 50-day and 200-day MA

$$SMA = \frac{A_1 + A_2 + \cdots + A_n}{n}$$

$$A_n = asset\ price\ at\ period\ n$$
$$n = total\ number\ of\ periods$$

How it works

Fast and **slow** MAs will have different sensitivities to stock price fluctuations

- Fast MA can indicate a **change in momentum** of the stock price in the future

We produce signals based on the **relationship** between the slow and fast MA

- **Buy/sell** dependant on slow and fast averages crossing

Let’s visualise this!

Interpreting moving averages crossing

Fast MA – red

Slow MA – blue

Stock – candlestick

What could fast crossing above or below the slow mean?

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What could fast crossing above or below the slow mean?

- **Fast above slow: upward momentum**
- **Fast below slow: downward momentum**

Interpreting moving averages crossing

MA crossovers can indicate **momentum shifts**, enabling us to enter the market as the price shifts direction

Fast crossing **above** slow indicates the stock has **upward momentum**

- This results in a **buy** signal (bullish)

Fast crossing **below** slow indicates the stock has **downward momentum**

- This results in a **sell** signal (bearish)

Quick detour into some terminology

Bullish and bearish market sentiments

- **Bullish sentiment**: a positive outlook expecting stock prices to rise, as a result of increased buying activity (stock will rise)

- **Bearish sentiment**: a negative outlook expecting stock prices to fall, as a result of increased selling activity (stock will fall)

Long and short positions

Taking a '**long**' position on a stock means buying the stock with the expectation its price will **rise**, allowing us to sell later at a profit

- **Go long** when the fast MA crosses **above** the slow MA
- Close the trade (sell) when momentum slows (fast MA **flattens** or starts to fall)

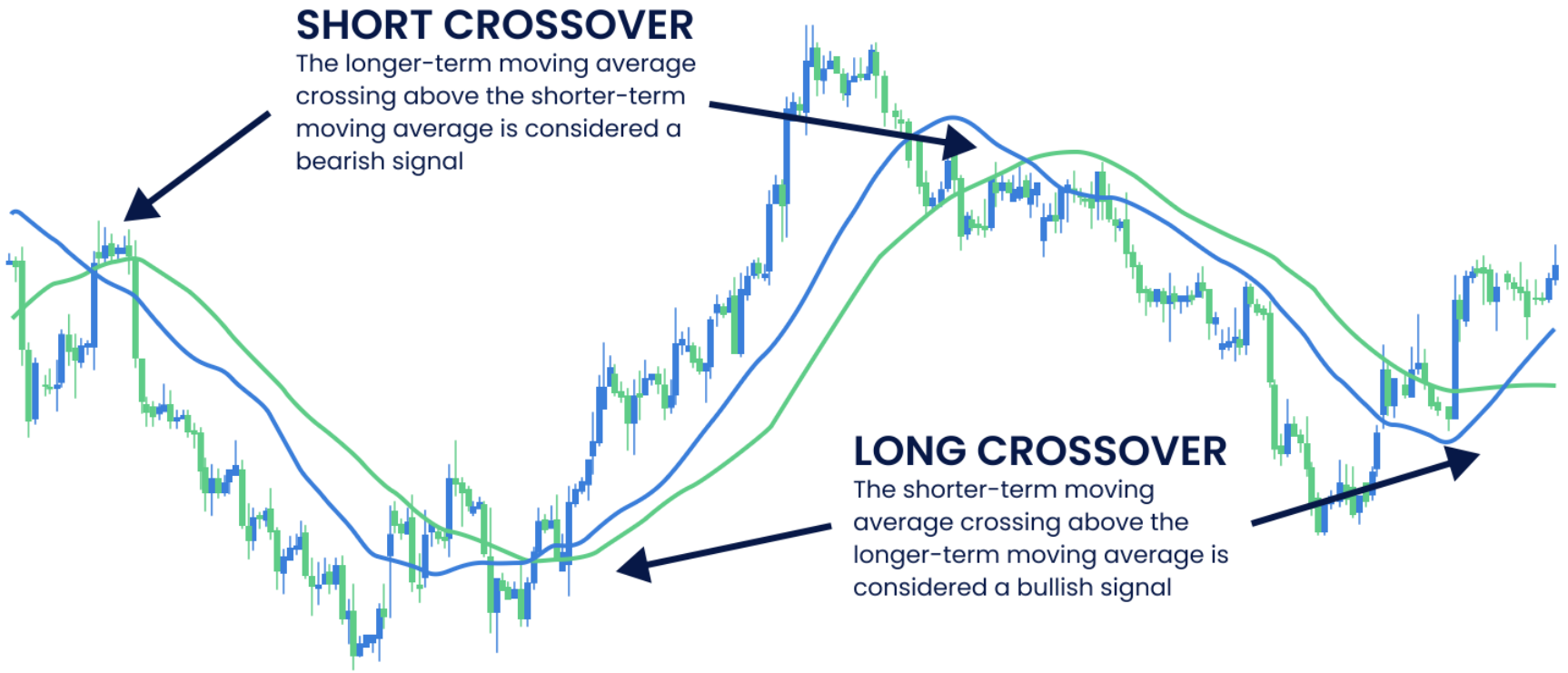
Long and short positions

'**Going short**' means borrowing shares to sell immediately, with the expectation prices will fall, to then buy back later and return to the **broker**, making the profit

- **Go short** when the fast MA crosses **below** the slow MA
- Close the trade (buy) when momentum slows (fast MA **flattens** or starts to rise)

Long and short crossovers illustrated

Blue – fast MA
Green – slow MA



Moving averages in action

Blue – fast MA
Red – slow MA
Candlesticks – stock

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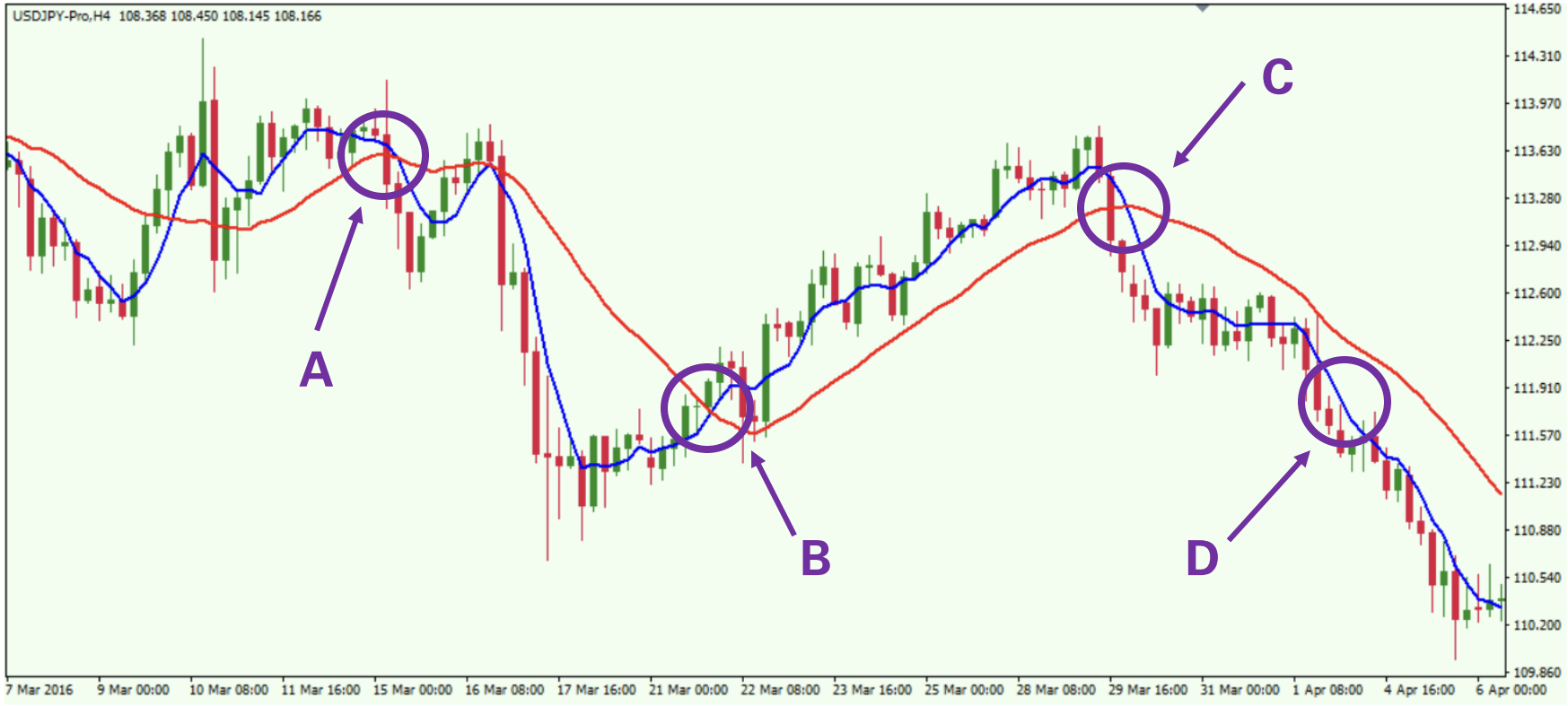
What would we do at

- *A?*
- *B?*
- *C?*
- *D?*



Moving averages in action

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What would we do at

- *A?* **Sell**
- *B?*
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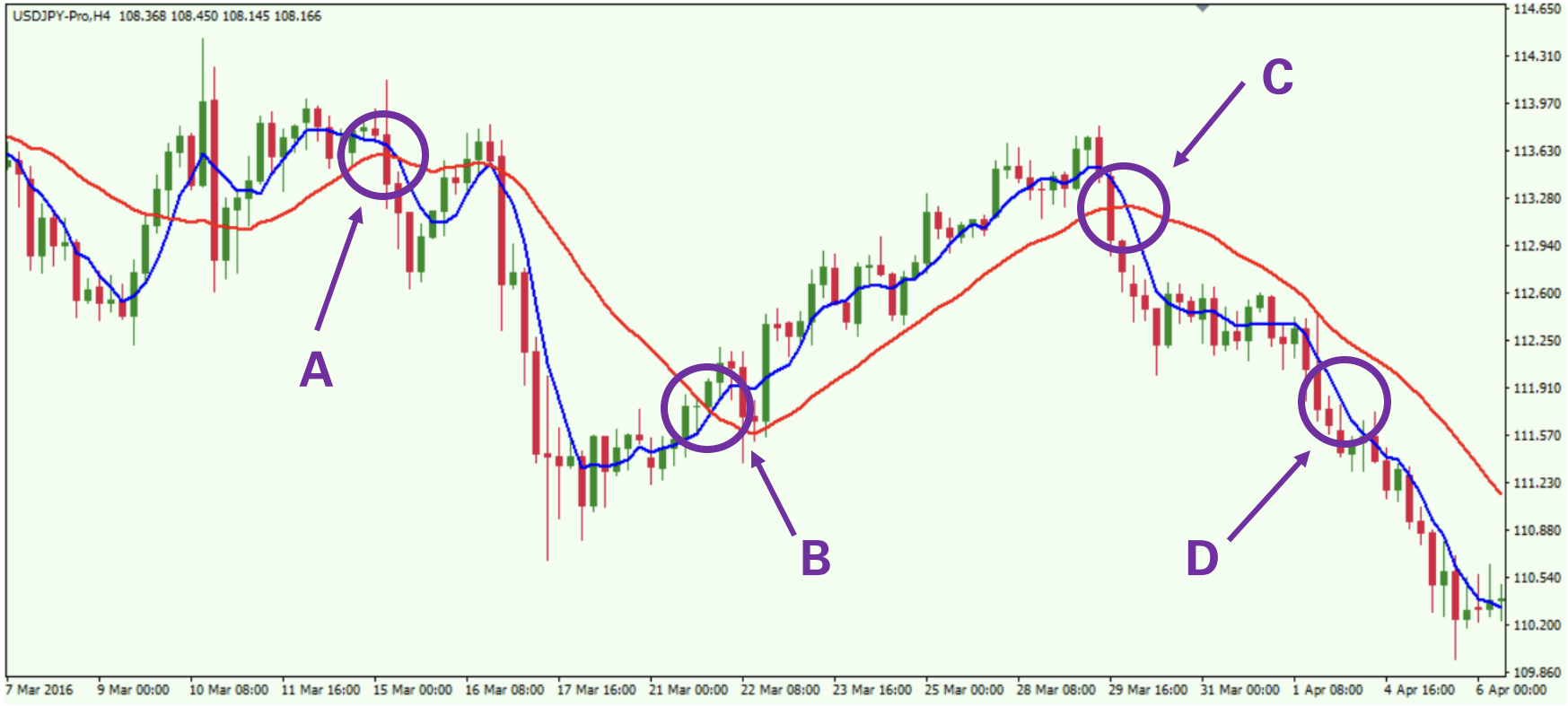

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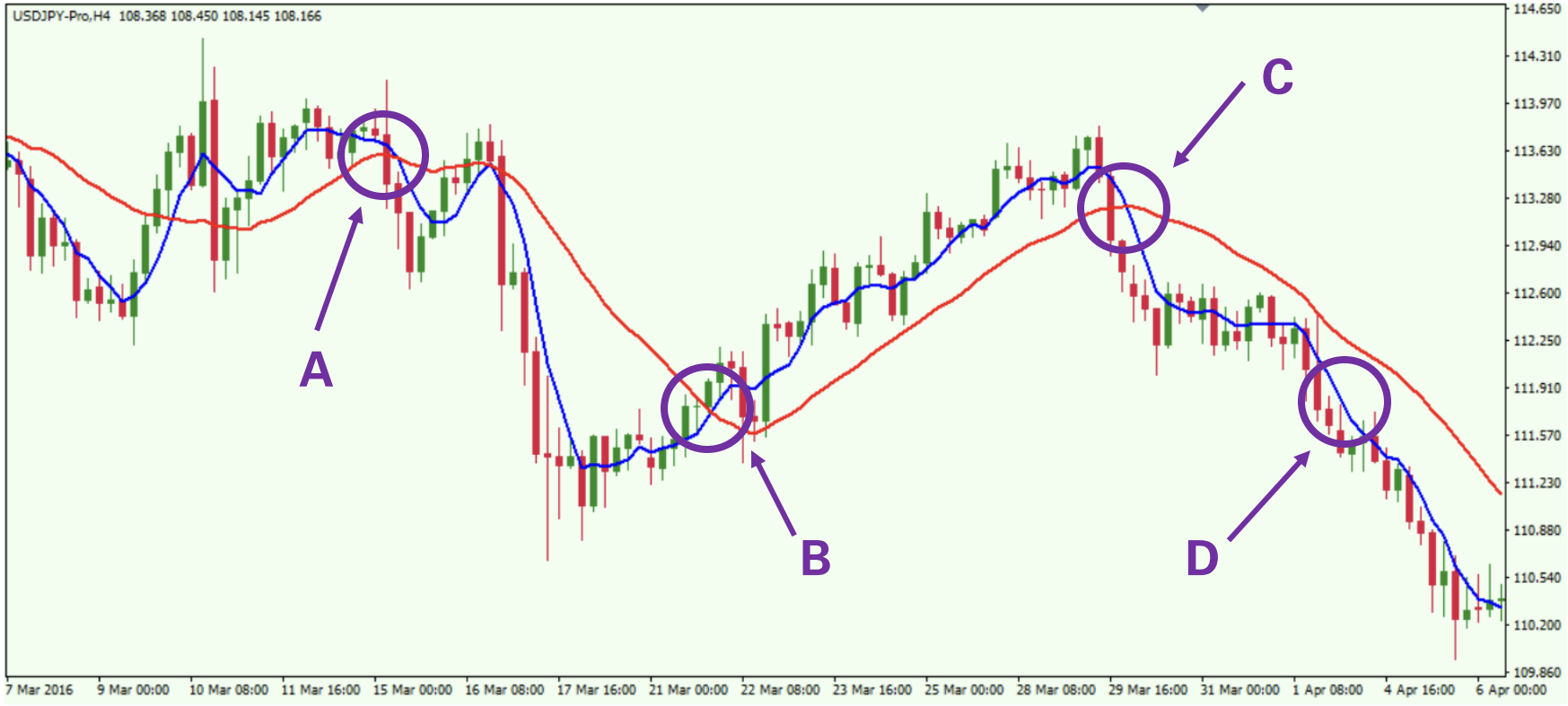

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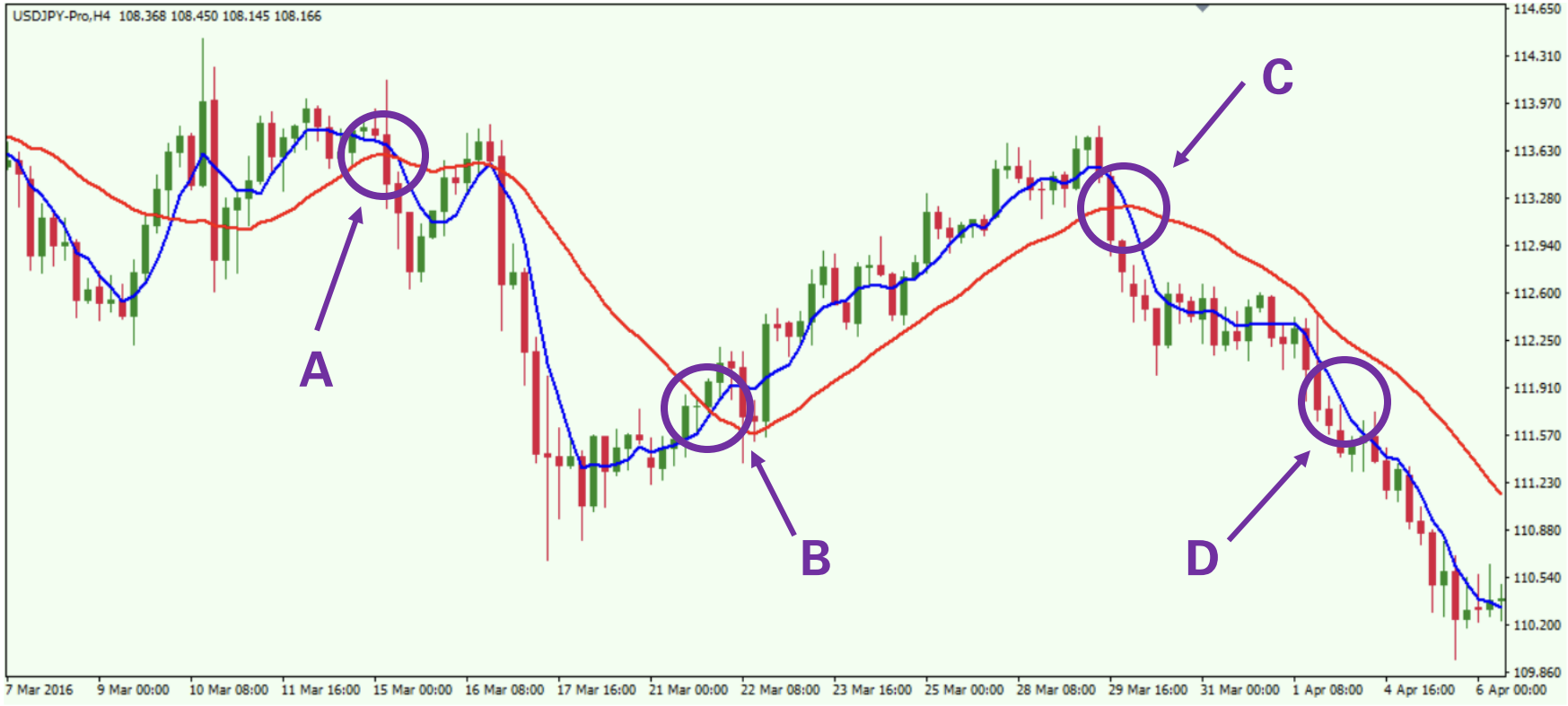
What would we do at

- *A?* **Sell**
- *B?* **Buy**
- *C?* **Sell**
- *D?*



Moving averages in action

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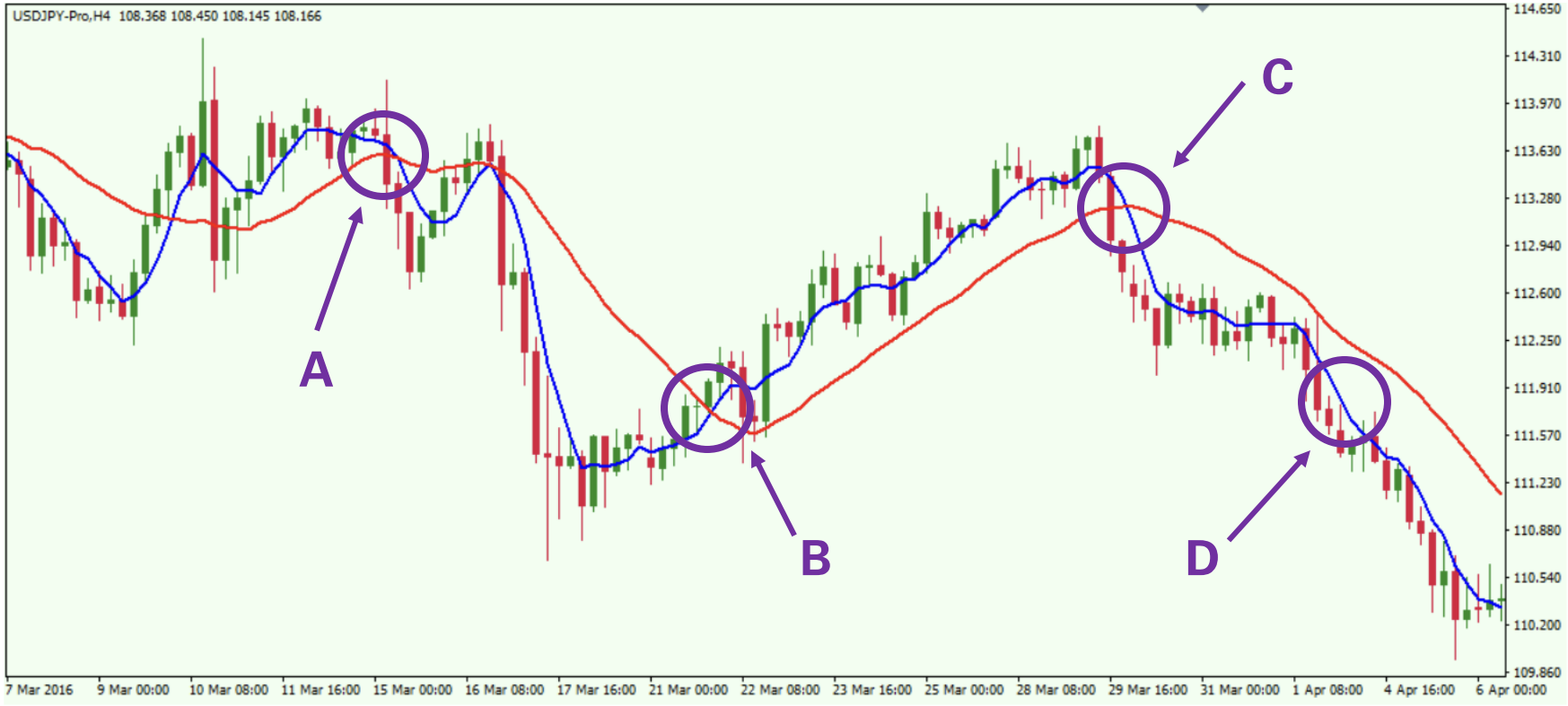
What would we do at

- *A?* **Sell**
- *B?* **Buy**
- *C?* **Sell**
- *D?* **Nothing**



But our MA here seems to be a bit slow…

Could we use a **different** type of moving average that responds **quicker** to changes in price trends, to **maximise our profit**?

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Could we use a **different** type of moving average that responds **quicker** to changes in price trends, to **maximise our profit**?

Weighted Moving Average!

Weighted moving average

- Moving average formula applying **linear** weights to each period
- More **recent periods** having higher weights, thus **greater influence** the average

$$WMA = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

$$x_i = value\ of\ assets\ at\ i^{th}\ period$$
$$w_i = weight\ of\ asset\ at\ i^{th}\ period$$
$$n = total\ number\ of\ periods$$
$$i = sum\ of\ all\ weights$$

What about an even more responsive MA?

Exponential Moving Average

- EMA is a **recursive** formula, giving **exponentially** more **weight** to recent prices
- It is very **responsive** to recent changes in market price

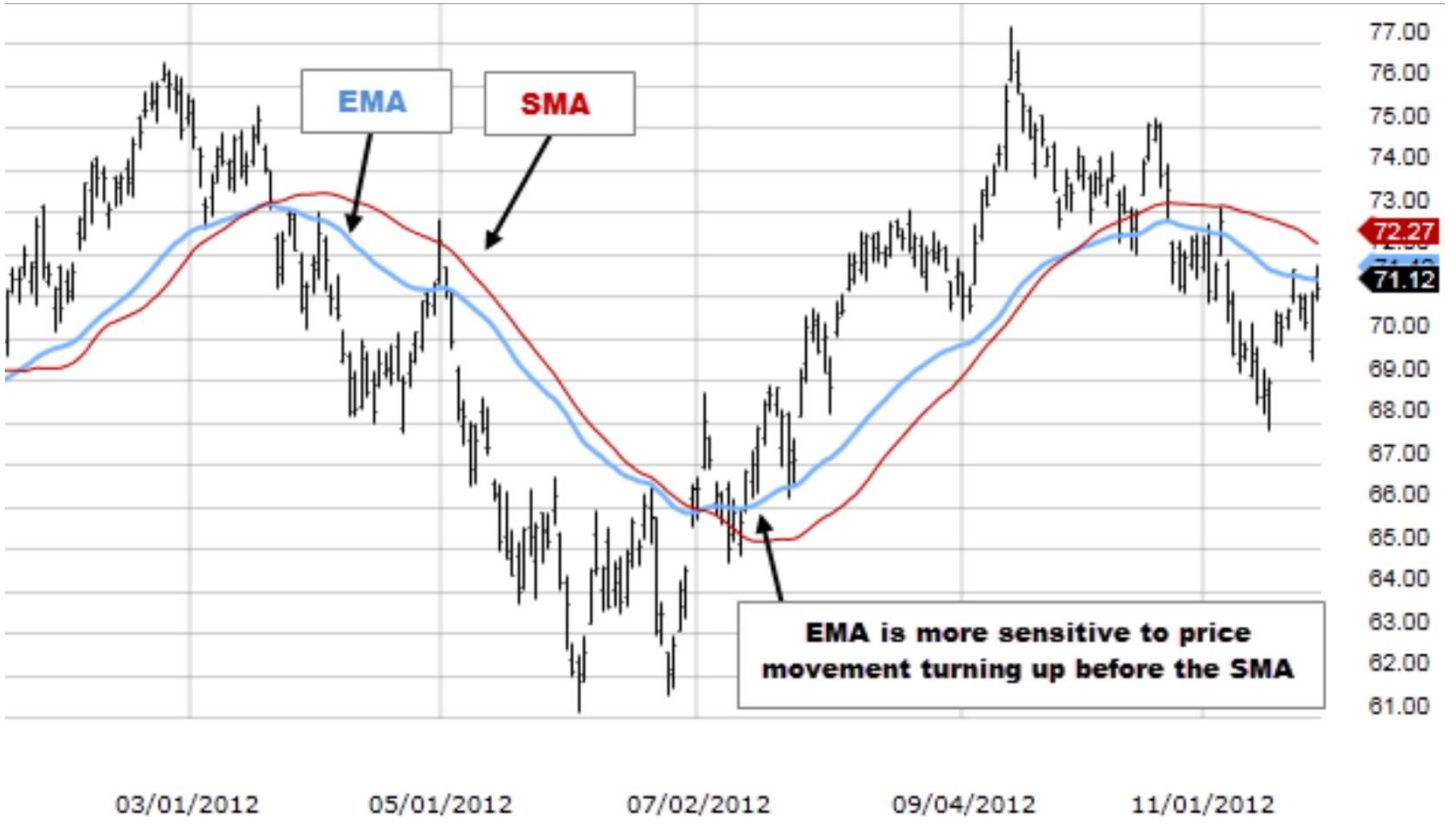
$$EMA_t = Price(t) \times k + EMA_{t-1} \times (1 - k)$$

$$t = today$$
$$n = number\ of\ days$$
$$k = smoothing\ factor, \frac{2}{1+n}$$

EMA vs. SMA

EMA is more sensitive, helping to **identify trends earlier**…

…but does experience more sudden **short-term** changes

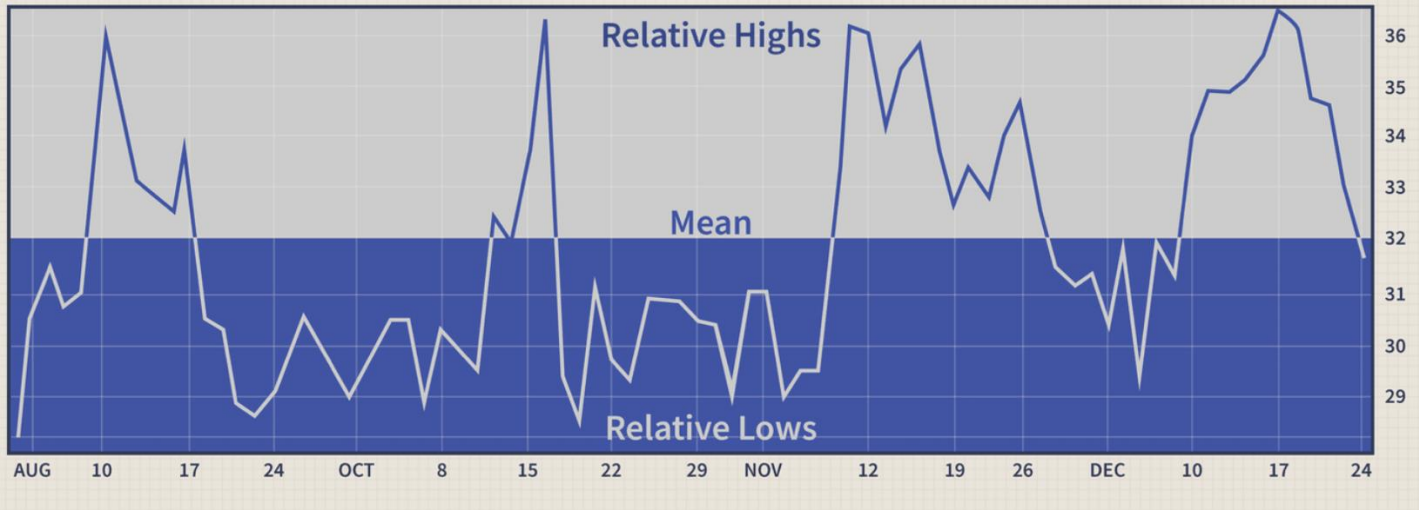


Mean reversion

“Things will return to normal”

Mean reversion

Strategy based on the principle that asset prices will **return** to their historical average, or **mean**, after **deviating from it**



In reality a stock's **mean won't be flat**, but this diagram illustrates the principle well

Key concepts / Theory

Asset prices **naturally fluctuate** above/below their historical rolling average

- From changing market conditions, news, investor sentiment etc.

We assume extreme price fluctuations are **temporary**, and prices will **revert** to their historical average

Theory based on **efficient market hypothesis** and **investor behavioural biases**

- Investors overreact to market news etc
- A stock's price is reflective of all available information

How it works

- Use **rolling averages** to determine the mean price of an asset
- Set **bounds**, representing limits for normal fluctuations, beyond which we enter a trade
- Open positions when the stock fluctuates, and profit when the price **reverts** to its historical average

Let’s visualise this!

How it works

- Enter trade when the price fluctuates
- Close when it reverts
- Profit the difference!

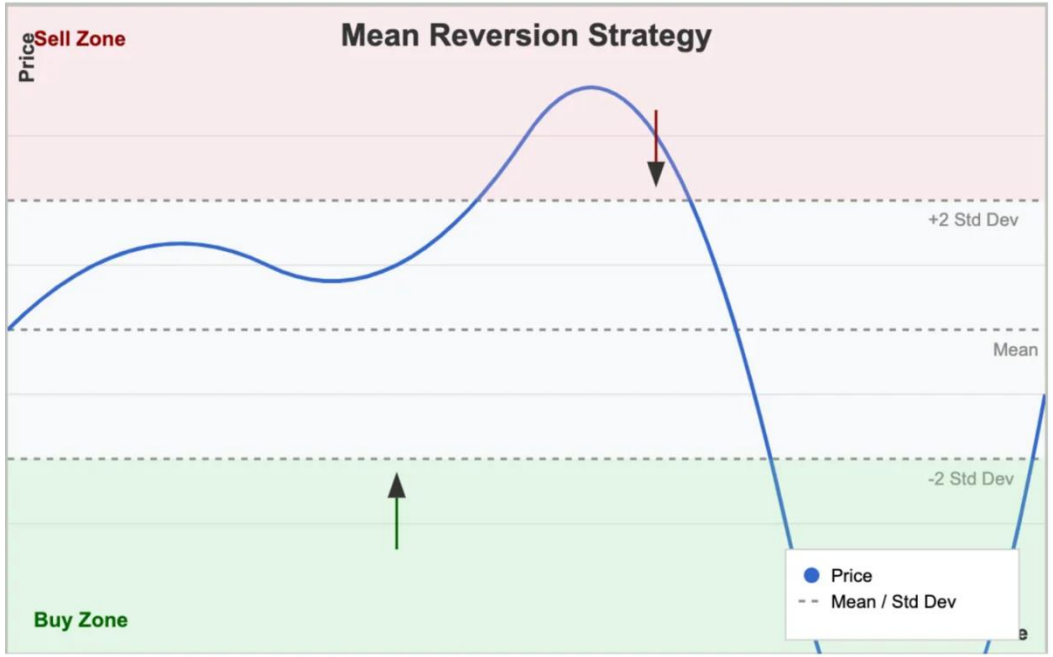
What do we mean by ‘bounds’ and how do we set these?

Bounds / limits

Mathematical limits above and below an assets price, beyond which we enter a trade position

Common metrics include:

- **Bollinger bands**
- **Relative strength index**
- **Z-score**



Z-score

Z-score informs on how many **standard deviations** the current price is from the mean

$$Z = \frac{P - \mu}{\sigma}$$

$$P = current\ asset\ price, \mu = mean\ price, \sigma = standard\ deviation$$

Large **positive** or **negative** z-scores ($\geq |2|$) can indicate overbought or oversold assets

Sanity check

If the price is **2 z-scores above/below** the mean, what do we do?

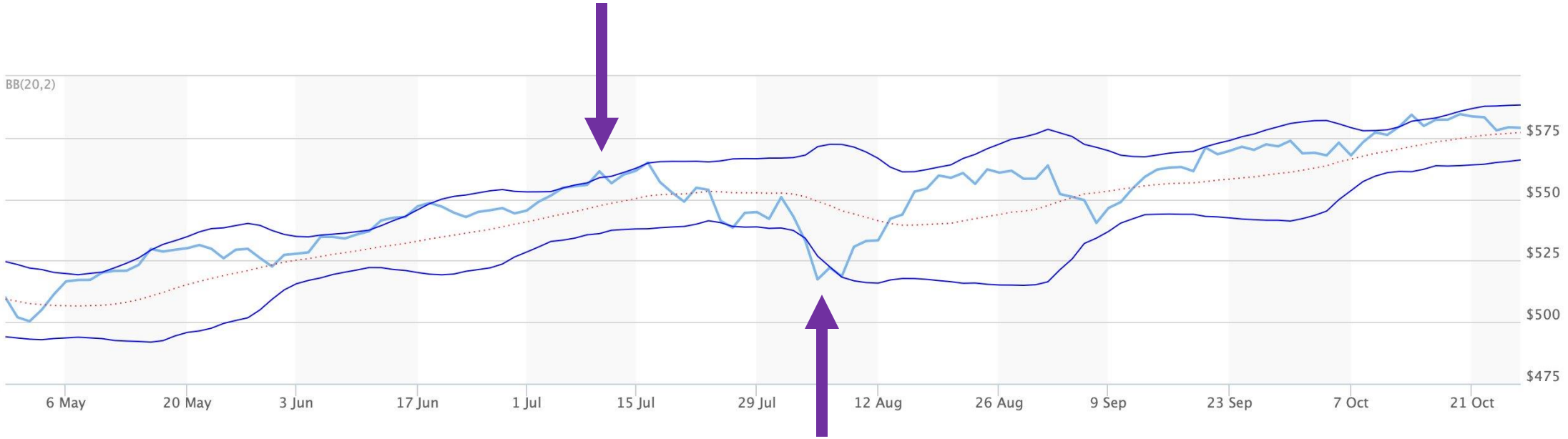
Sanity check

If the price is **2 z-scores above/below** the mean, what do we do?

- Above: take a **short** position, and close when the price reverts
- Below: take a **long** position, and close when the price reverts

Mean reversion in action

https://www.marketwatch.com/investing/index/spx/charts?mod=mw_quote_advanced



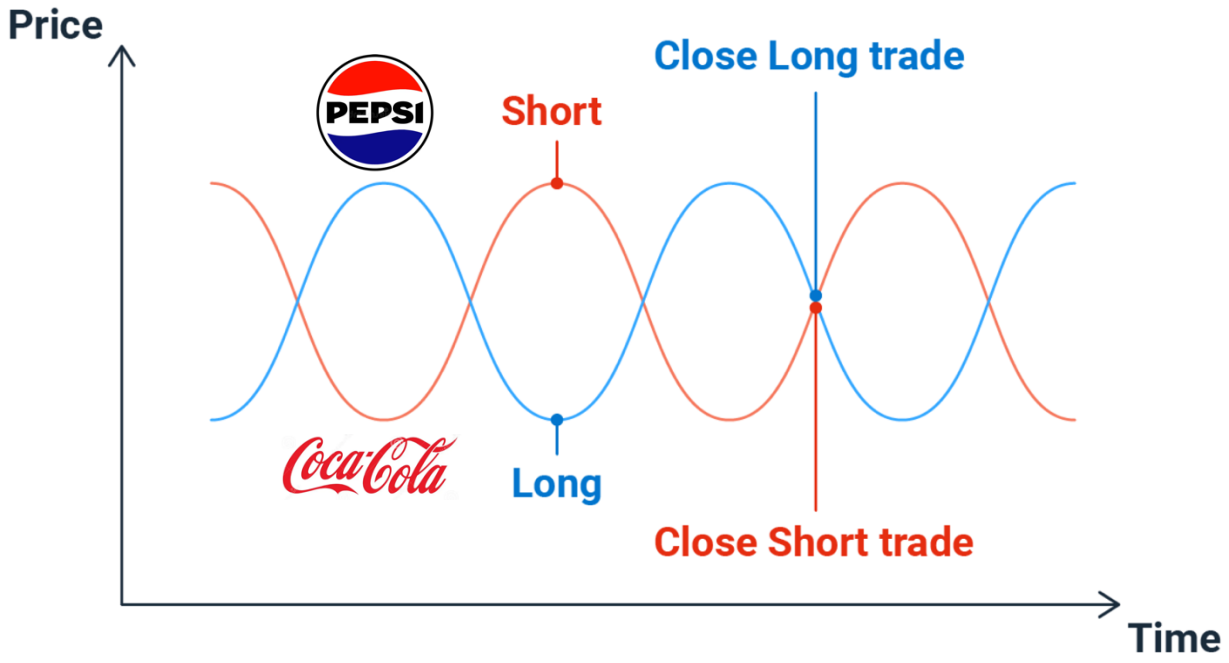
Pairs trading

Any ideas….?

….trading a pair of assets

Pairs trading

A strategy that profits off **temporary deviations** in the price relationship of two **highly correlated** assets



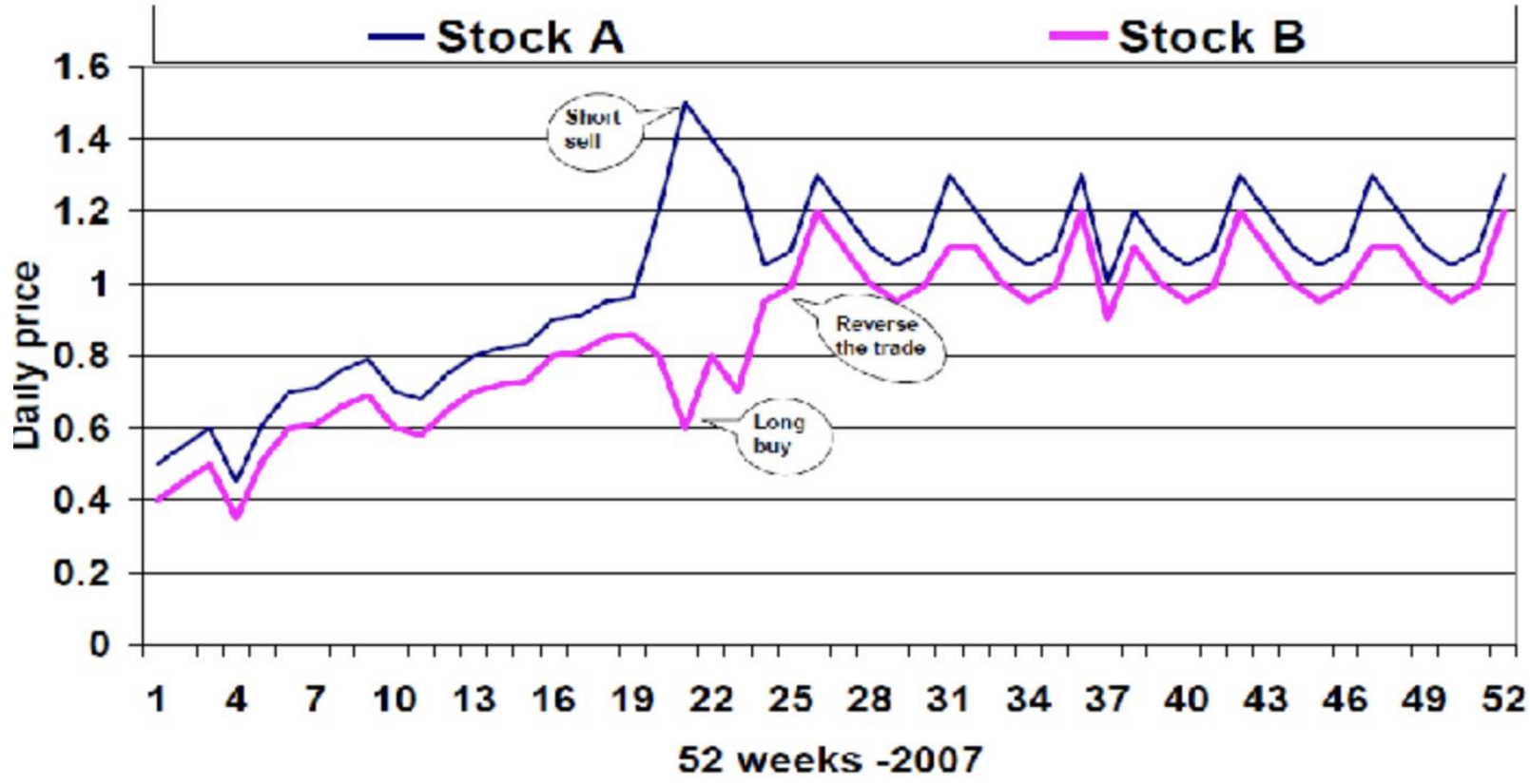
Key Concepts

Monitoring the **price divergence** between a pair of **highly correlated assets**

The price difference is referred to as the ”**spread”**, and when the spread diverges (greater than set **bounds**) it presents a trading opportunity

Long the undervalued asset and **short** the overvalued, and close both trades once they revert!

Pairs trading illustrated



How it works

- Asset pairs are identified through correlation or cointegration
- Spread is calculated as the **difference** between asset prices ($A_1 - A_2$) or by looking at the **ratio** of their prices
- **Z-scores** or **standard deviation** are used to set bounds for the spread

Monitoring spread

- We calculate **spread of assets*** via a **ratio** of their prices

$$Spread = \frac{P_A}{P_B}$$

$$P_x = price\ of\ asset\ x$$

- Set **z-score bounds** based on **deviations** from their historical spread

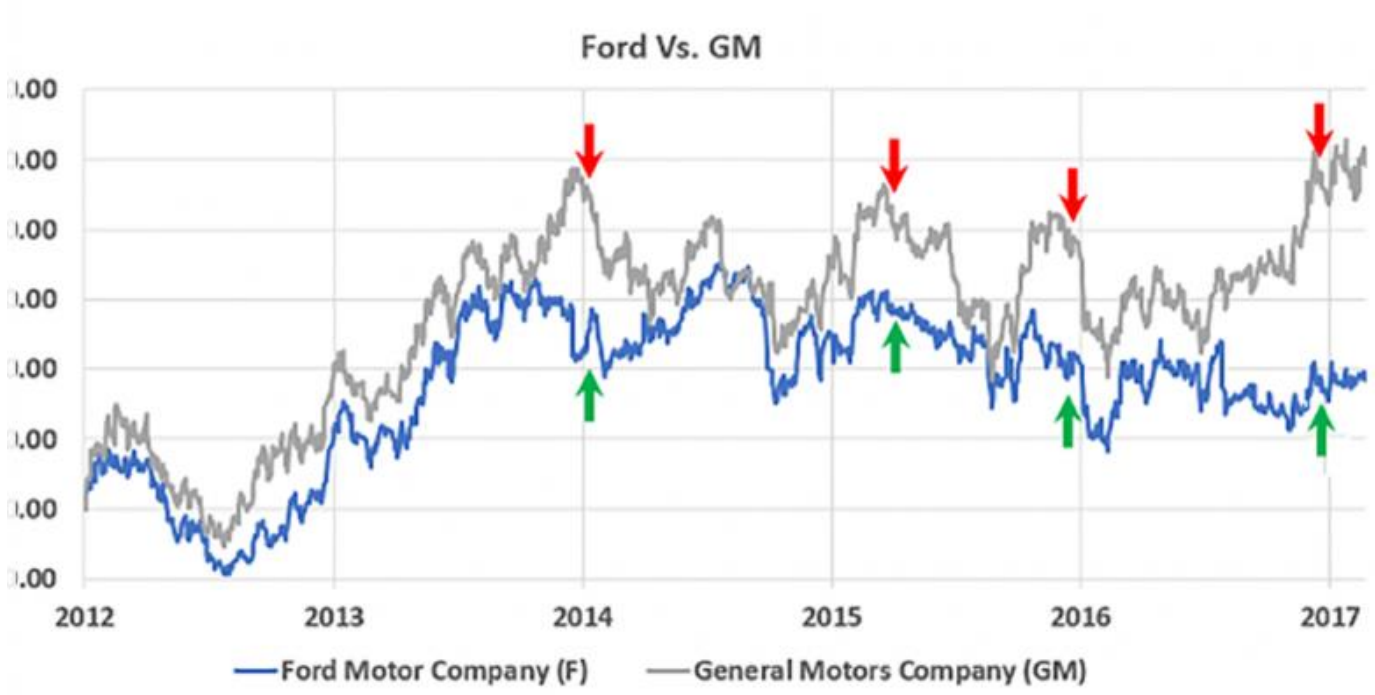
*the hedge ratio approach is another common way to calculate spread

Pairs trading in action

Grey – GM

Blue – Ford

What positions would we take in 2014?



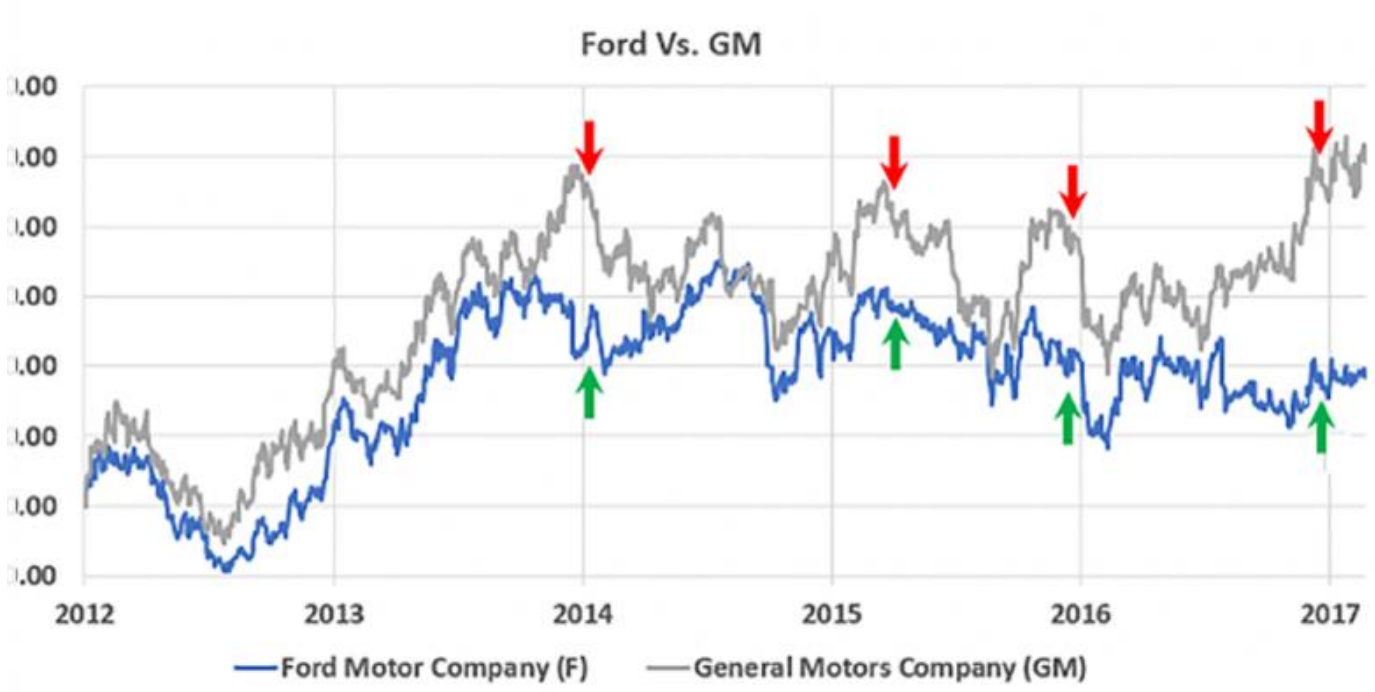
Pairs trading in action

Grey – GM

Blue – Ford

What positions would we take in 2014?

- **Short GM**
- **Long Ford**



Assessing an algorithm’s performance

Ways to assess an algorithms performance?

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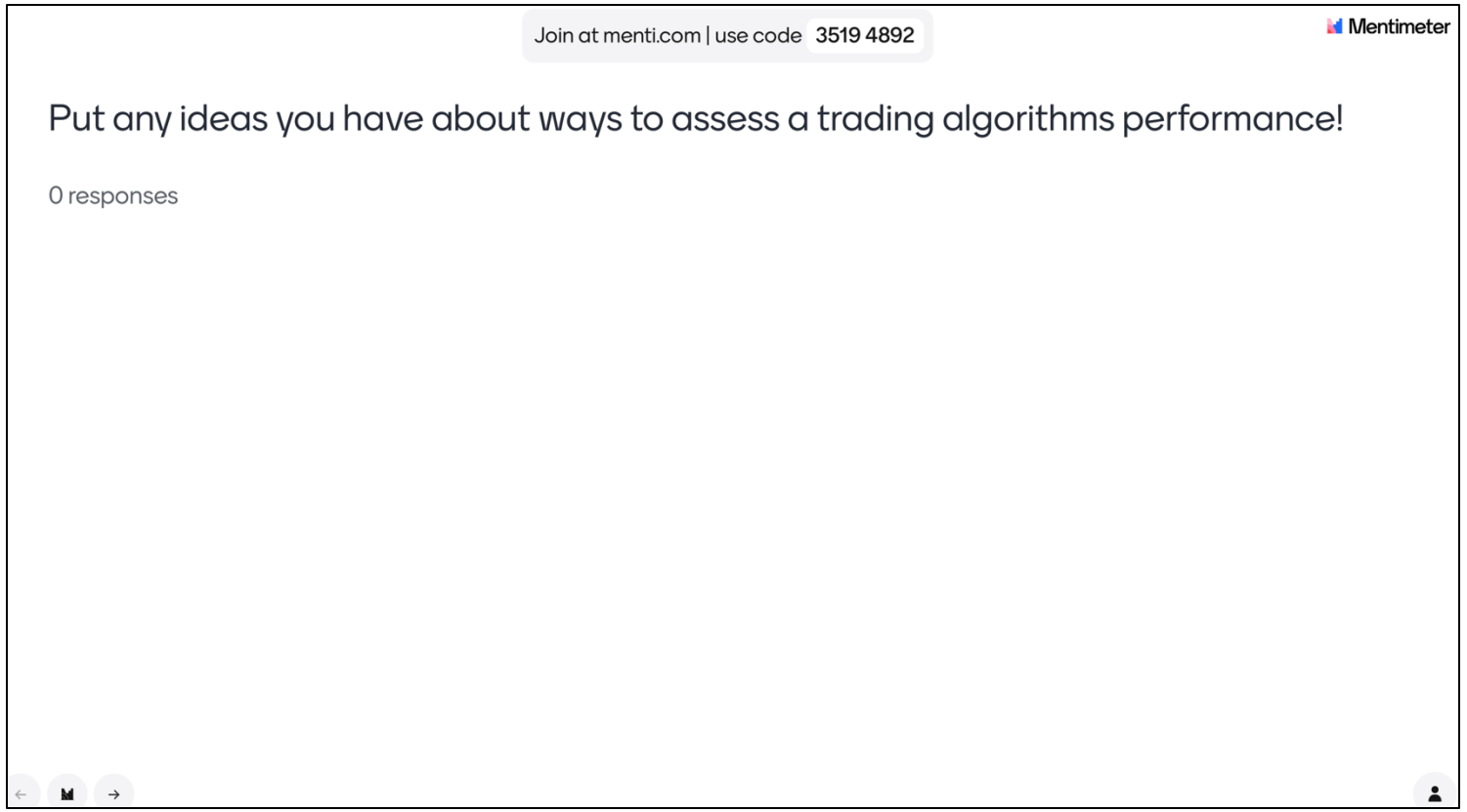
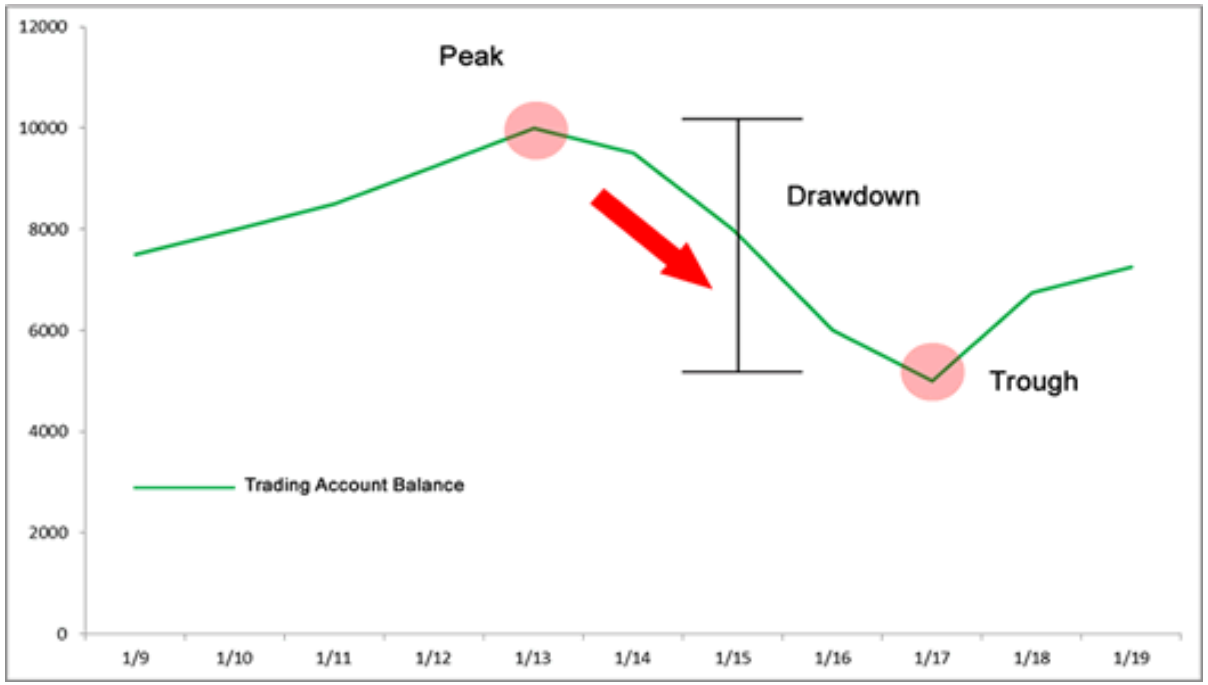


Drawdown

What is drawdown?

Drawdown

The **peak-to-trough decline** during a specific period for an investment, typically measured as a percentage from the peak.



Types of drawdown...

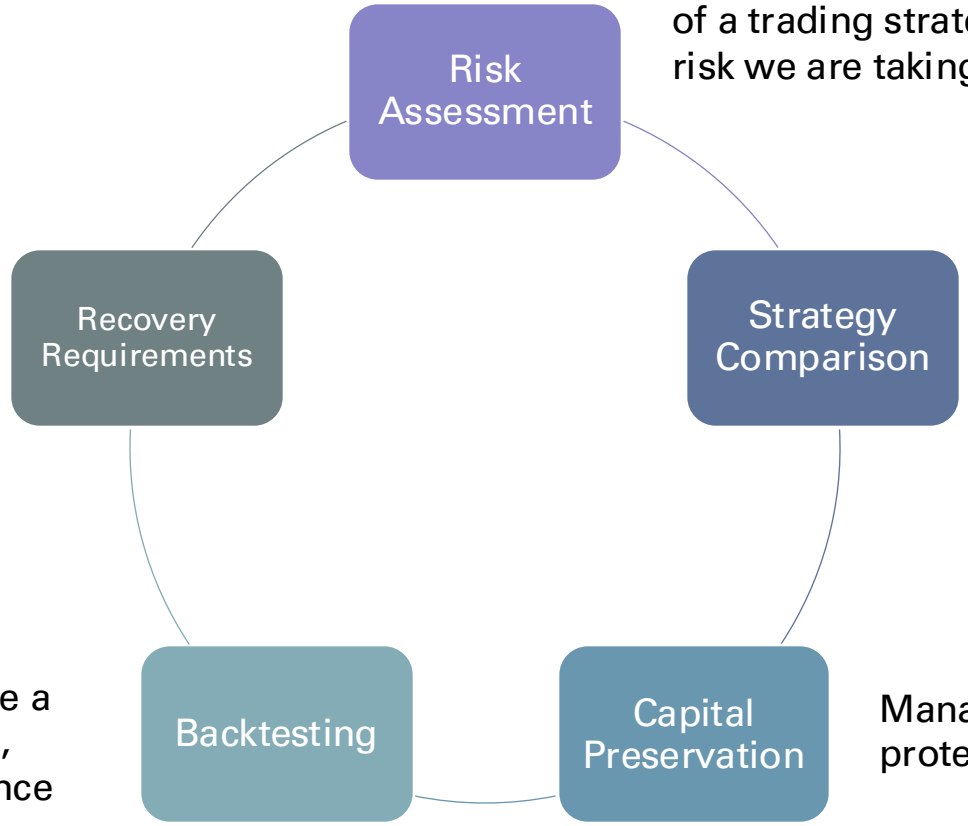
Maximum Drawdown: The largest drop from a peak to a trough over the trading period

Relative Drawdown: Percentage decline from the highest equity point relative to the account balance

Why do we use drawdown?

Drawdown helps quantify the potential downside of a trading strategy. We can gauge how much risk we are taking on worst-case!

Drawdown highlights the recovery hurdle. A 50% drawdown requires a 100% gain to break even!



Drawdown allows us to identify which strategies are riskier

Measuring drawdown helps validate a strategy under historical conditions, revealing its robustness and resilience

Managing drawdown is essential for protecting trading capital

What causes high drawdown?

High volatility!

How can we measure volatility?

Measuring volatility

Standard deviation: widely regarded as a highly effective measure of volatility - it quantifies how much returns deviate from the average

Higher standard deviation implies more variability (volatility) in returns, while a lower standard deviation indicates returns are closer to the average, suggesting less volatility.

Putting it all together we end up with…

Sharpe Ratio!

Sharpe Ratio

The Sharpe ratio aims to measure how much additional return an investor earns by taking on additional risk, beyond the risk-free rate.

$$S = \frac{R_p - R_f}{\sigma_p}$$

R_p = Expected return (or actual return) of the portfolio/investment

R_f = Risk-free rate (e.g., return of government bonds)

σ_p = Standard deviation of the portfolio's returns (a measure of risk or volatility)

Sharpe Ratio: the amount of return PER risk!

Python notebook