

# L34: AMM Mechanics

## Module E: DeFi Ecosystem

Blockchain & Cryptocurrency

December 2025

- Understand the constant product formula ( $x \cdot y = k$ )
- Analyze how liquidity provision works in AMMs
- Calculate impermanent loss and its implications
- Understand slippage and price impact
- Compare AMMs to traditional order book exchanges

# Traditional Order Book Exchanges

## How They Work:

- **Buyers** place bids, **sellers** place asks
- **Matching engine** pairs buy/sell orders
- Trade executes when bid meets ask

## Example Order Book:

	Price	Size
<b>Bids (Buy)</b>		
	\$1,999	5 ETH
	\$1,998	10 ETH

	Price	Size
<b>Asks (Sell)</b>		
	\$2,000	8 ETH
	\$2,001	12 ETH

**Challenges on Blockchain:** Gas costs for order updates, slow block times, front-running.

# Automated Market Makers (AMMs)

**Key Idea:** Replace order books with liquidity pools governed by mathematical formulas.

## How It Works:

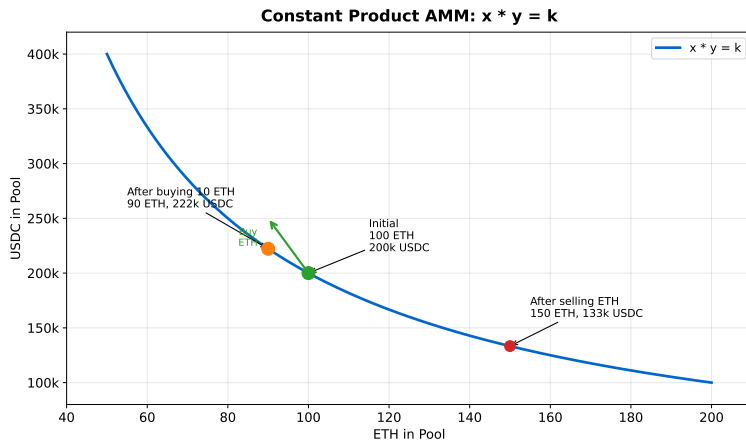
- Liquidity Providers (LPs) deposit token pairs into a pool
- Algorithm sets price based on pool ratio
- Users trade directly against the pool

## Advantages:

- Always available liquidity (no need to wait for orders)
- Passive income for LPs (earn trading fees)
- Gas efficient (fewer transactions)

**Trade-off:** Price determined by formula, not market consensus.

# The Constant Product Formula



*Trades move along the curve; price is the slope at any point*

## Uniswap V2 Model:

$$x \cdot y = k$$

where  $x$  = token A quantity,  $y$  = token B quantity,  $k$  = constant.

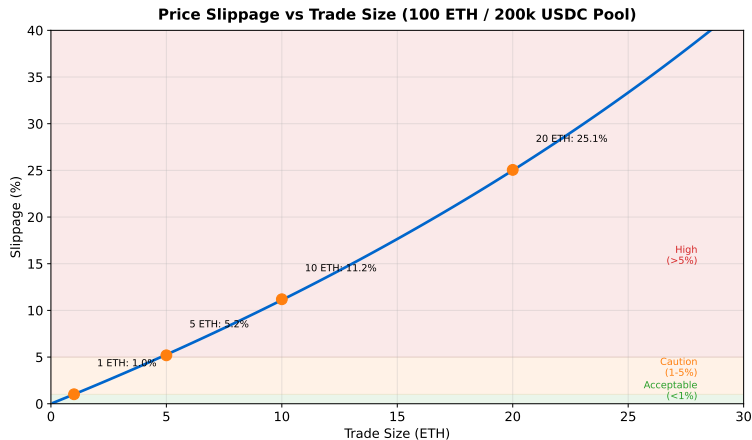
## Example Pool:

- 100 ETH and 200,000 USDC
- $k = 100 \times 200,000 = 20,000,000$
- Price:  $\frac{y}{x} = \frac{200,000}{100} = 2,000$  USDC per ETH

## After Buying 10 ETH:

- New ETH: 90, New USDC:  $\frac{20,000,000}{90} = 222,222$
- Cost: 22,222 USDC for 10 ETH = \$2,222/ETH average

# Slippage vs Trade Size



*Slippage increases non-linearly; larger pools reduce slippage*

**Definition:** The difference between expected price and executed price due to trade size.

## Why Slippage Occurs:

- AMM formula moves price as reserves change
- Larger trades = larger price impact
- Smaller pools = more slippage

## Slippage Formula:

$$\text{Slippage} = \frac{\text{Executed Price} - \text{Initial Price}}{\text{Initial Price}} \times 100\%$$

**Slippage Tolerance:** Users set maximum acceptable (e.g., 0.5%, 1%). Transaction reverts if exceeded.



## How to Become an LP:

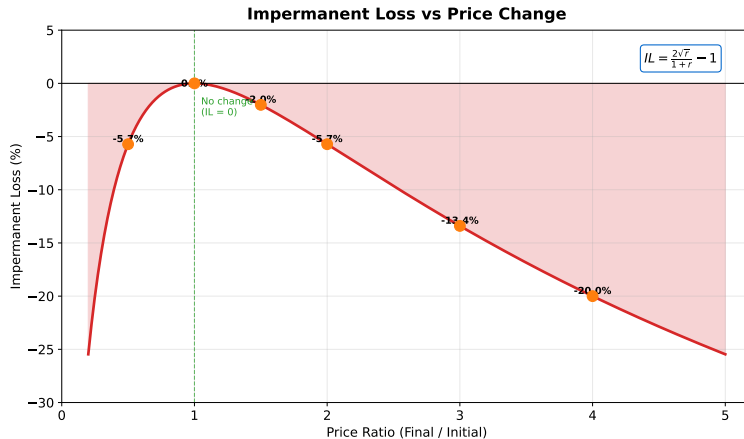
- 1 Deposit equal value of both tokens (e.g., 1 ETH + 2,000 USDC)
- 2 Receive LP tokens representing pool share
- 3 Earn trading fees proportional to share
- 4 Withdraw anytime (burn LP tokens, receive reserves)

## Example:

- Pool has 100 ETH + 200,000 USDC
- You deposit 10 ETH + 20,000 USDC
- Your share:  $\frac{10}{110} = 9.09\%$  of pool

**Fee Earnings:** Uniswap charges 0.3% per trade; fees compound in pool reserves.

# Impermanent Loss



*IL increases with price divergence; symmetric whether price rises or falls*

# Impermanent Loss: Concept

**Definition:** The opportunity cost of providing liquidity vs. simply holding tokens.

**Occurs when:**

- Token prices diverge from deposit ratio
- Arbitrageurs rebalance pool to match external prices
- LPs end up with more of the depreciated token

**Example: ETH doubles to \$4,000**

- Initial:  $1 \text{ ETH} + 2,000 \text{ USDC} = \$4,000 \text{ total}$
- If held:  $1 \text{ ETH} @ \$4,000 + 2,000 \text{ USDC} = \$6,000$
- If LP:  $0.707 \text{ ETH} + 2,828 \text{ USDC} = \$5,656$
- **IL: \$344 (5.7%)**

## Formula:

$$IL = \frac{2\sqrt{r}}{1+r} - 1$$

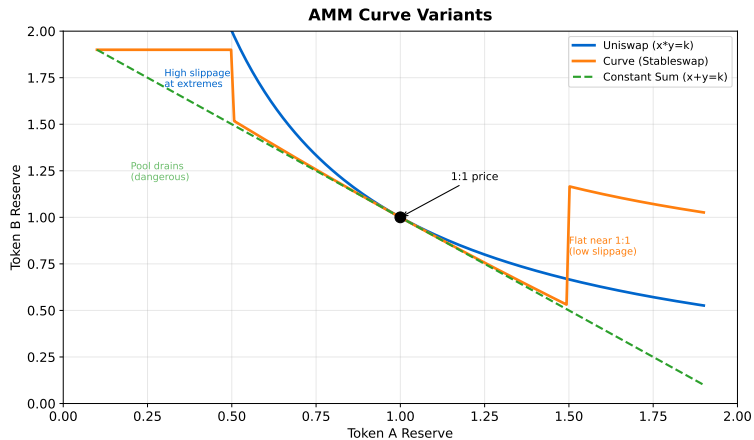
where  $r$  is the price ratio (final/initial).

## Common Scenarios:

- 1.25x price change: -0.6% IL
- 1.5x price change: -2.0% IL
- 2x price change: -5.7% IL
- 3x price change: -13.4% IL
- 4x price change: -20.0% IL

**Why “Impermanent”?** Loss only realized on withdrawal; if prices return, loss disappears.

# AMM Curve Variants



*Different curves optimize for different use cases*

## Uniswap (Constant Product): $x \cdot y = k$

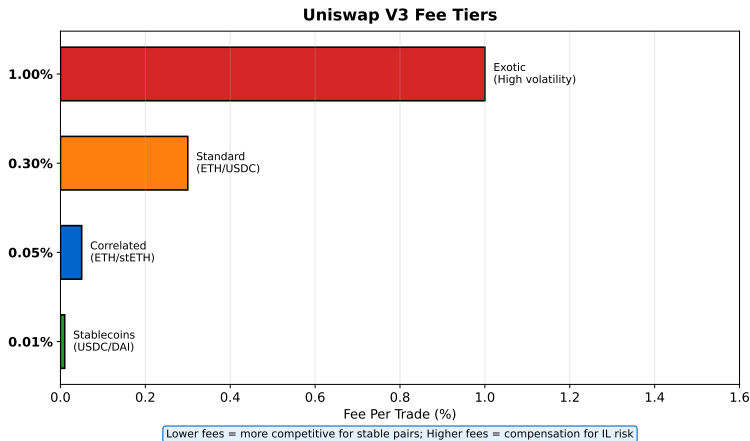
- General purpose, works for any pair
- Higher slippage near extremes

## Curve (Stableswap): Hybrid formula

- Flat curve near 1:1 (low slippage for stables)
- Dominates stablecoin swaps (USDC/DAI)

## Balancer (Weighted): $\prod x_i^{w_i} = k$

- Custom weights (e.g., 80/20 instead of 50/50)
- Index fund functionality



*Higher fees compensate LPs for impermanent loss risk in volatile pairs*

## How Arbitrage Works:

- 1 External market price deviates from AMM price
- 2 Arbitrageur buys cheaper asset, sells expensive one
- 3 AMM pool rebalances to match external price

## Example:

- CEX: 1 ETH = \$2,100
- Uniswap pool: 1 ETH = \$2,000
- Arbitrageur: Buy on Uniswap, sell on CEX, profit \$100/ETH

**Benefit:** Keeps AMM prices aligned with global markets.

**Cost:** LPs experience impermanent loss from adjustments.



## Maximal Extractable Value (MEV):

- Profit from reordering/inserting transactions
- Particularly prevalent in AMM trades

## Common MEV Strategies:

- 1 **Front-Running:** See large buy, buy first, sell after
- 2 **Sandwich Attacks:** Buy before user, sell after
- 3 **Arbitrage:** Exploit price differences

## Mitigation:

- Private mempools (Flashbots Protect)
- Batch auctions (CoW Swap)

## AMM (Uniswap)

- Always available liquidity
- Passive LP income
- Slippage on large trades
- Impermanent loss risk

## Order Book (Binance)

- Liquidity depends on makers
- Active market making
- Better for large trades
- No impermanent loss

**Trend:** Hybrid models emerging (e.g., dYdX order book on Cosmos).

## Key Takeaways:

- AMMs use  $x \cdot y = k$  to provide algorithmic liquidity
- Price determined by reserve ratio; trades move price
- Slippage increases non-linearly with trade size
- LPs earn fees but face impermanent loss when prices diverge
- IL formula:  $\frac{2\sqrt{r}}{1+r} - 1$  (up to 20%+ for 4x moves)
- Curve optimizes for stables; Balancer for weighted pools
- MEV is a hidden cost for AMM traders

**Next Lecture:** Uniswap Deep Dive - V1 to V4 evolution, concentrated liquidity.

- 1 Calculate the cost to buy 5 ETH from a pool with 100 ETH and 200,000 USDC.
- 2 Why does slippage increase non-linearly with trade size?
- 3 How do trading fees help offset impermanent loss for LPs?
- 4 Why is Curve more suitable for stablecoin trading than Uniswap V2?
- 5 What are the trade-offs of concentrated liquidity in Uniswap V3?