

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		Price	Size
Bids (Buy)	\$1,999	5 ETH	Asks (Sell)	\$2,000	8 ETH
	\$1,998	10 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:

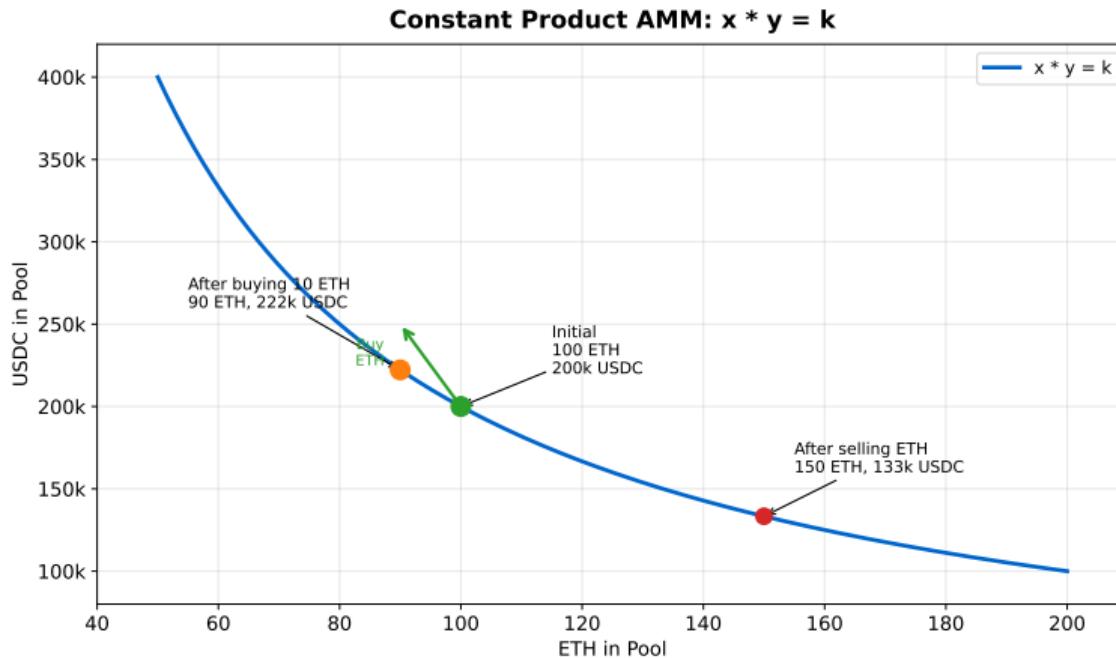
- Liquidity Providers (LPs) deposit token pairs into a pool
- Algorithm sets price based on pool ratio
- Users trade directly against the pool

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.

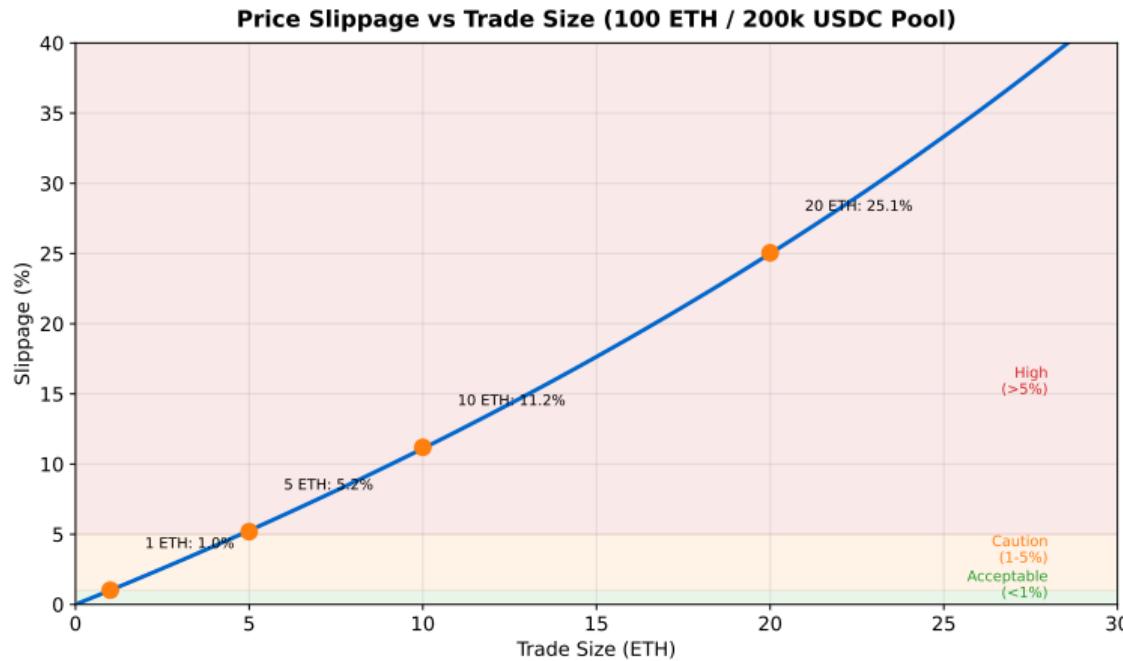
Example Pool:

- 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

Slippage Explained

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

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

Impermanent Loss: Key Values

Formula:

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

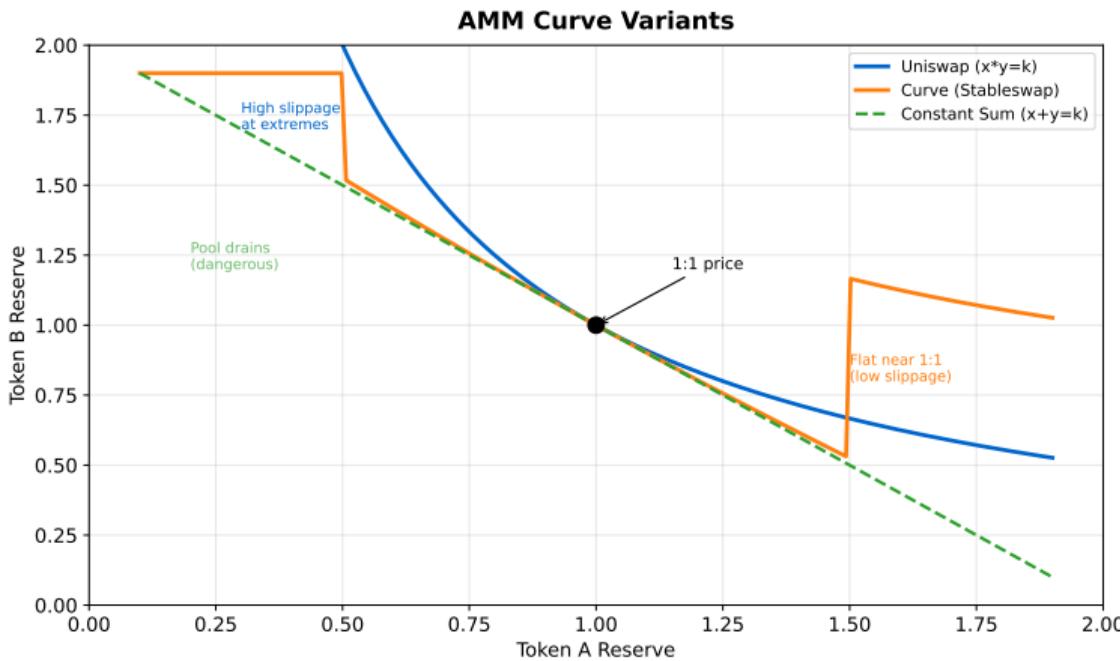
where r is the price ratio (final/initial).

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

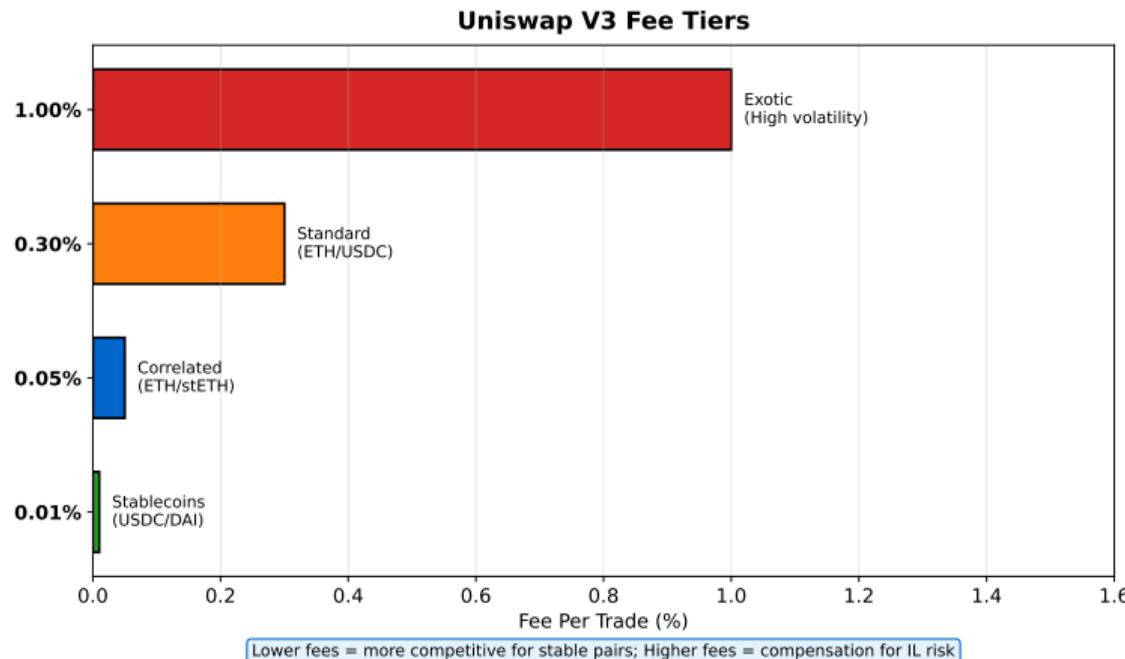
Curve (Stableswap): Hybrid formula

- 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

Fee Tiers in AMMs



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)

Comparison: AMM vs Order Book

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.

Questions for Reflection

- 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?