Course II:

DeFi Primitives

3. Swaps and Loans

(i) Swaps

(c) Automated Market Makers

Swap

Automated Market Makers (AMMs)

- An Automated Market Maker (AMM) is a smart contract that holds assets on both sides of a trading pair and continuously quotes a price for buying and for selling.
- Based on executed purchases and sales, the contract updates the asset size behind the bid and the ask and uses this ratio to define its pricing function.
- The contract can also take into account more complex data than relative bid/ask size when determining price.
- From the contract's perspective, the price should be risk-neutral where it is indifferent to buying or selling.

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Naïve AMM

- A naive AMM might set a fixed price ratio between two assets.
- With a fixed price ratio, when the market price shifts between the assets, the more valuable asset would be drained from the AMM and arbitraged on another exchange where trading is occurring at the market price.
- The AMM should have a pricing function that can converge on the market price of an asset so that it becomes more expensive to purchase an asset from the trading pair as the ratio of that asset to the others in the contract decreases.

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Advantages of AMM

- Main benefit is the constant availability 24/7 and that a traditional counterparty is not necessary to execute a trade.
- These provisions are very important for smart contracts and DeFi development because of the guarantee that a user can exchange assets at any moment if necessary.
- A user maintains custody of her funds until she completes the trade, hence, counterparty risk is zero.

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Composable liquidity of AMM

- An additional benefit is *composable liquidity*, which means any exchange contract can plug into the liquidity and exchange rates of any other exchange contract.
- AMMs make this particularly easy because of their guaranteed availability and their allowing one-sided trading against the contract.
- Composable liquidity fits with concept of DeFi Legos.

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Impermanent loss of AMM

- One drawback to an AMM is the concept of *impermanent loss*, the opportunity-cost dynamic between offering assets for exchange and holding the underlying assets to potentially profit from the price movement.
- The loss is impermanent because it can be recovered if the price reverts to its original level.

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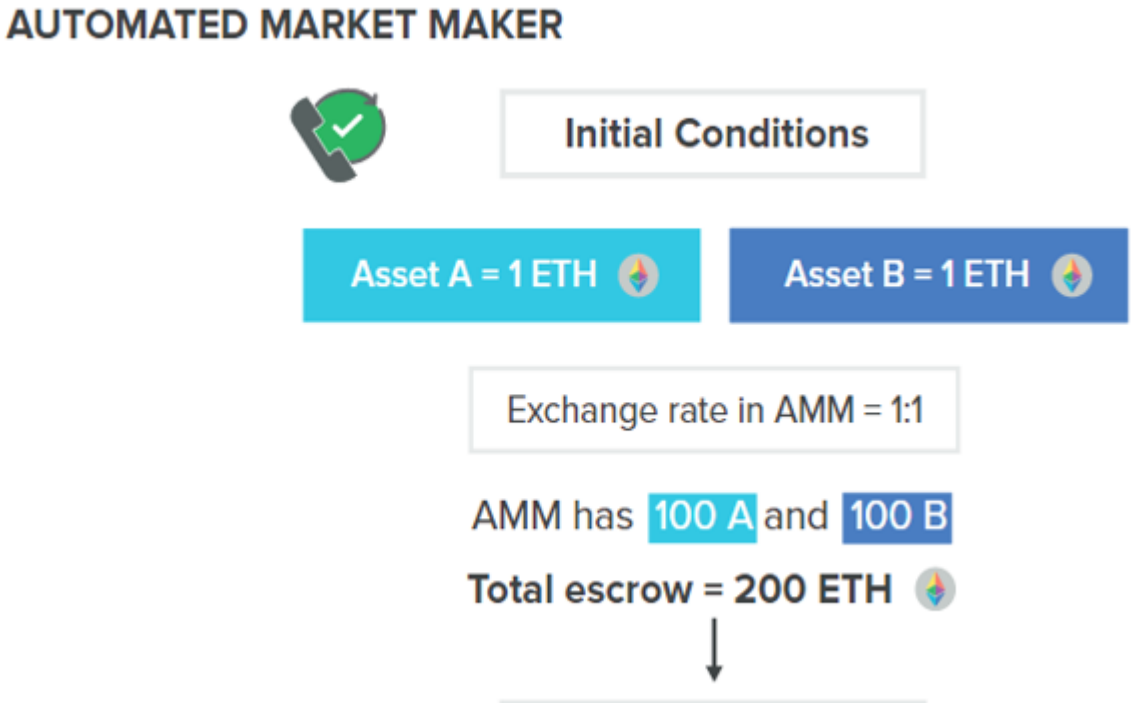
Impermanent loss example

- Initial conditions in market:
  - Token A = 1 ETH and
  - Token B = 1 ETH
- AMM has an exchange rate of 1:1
- Contract has 100 A and 100 B. So the total value of escrow is 200 ETH



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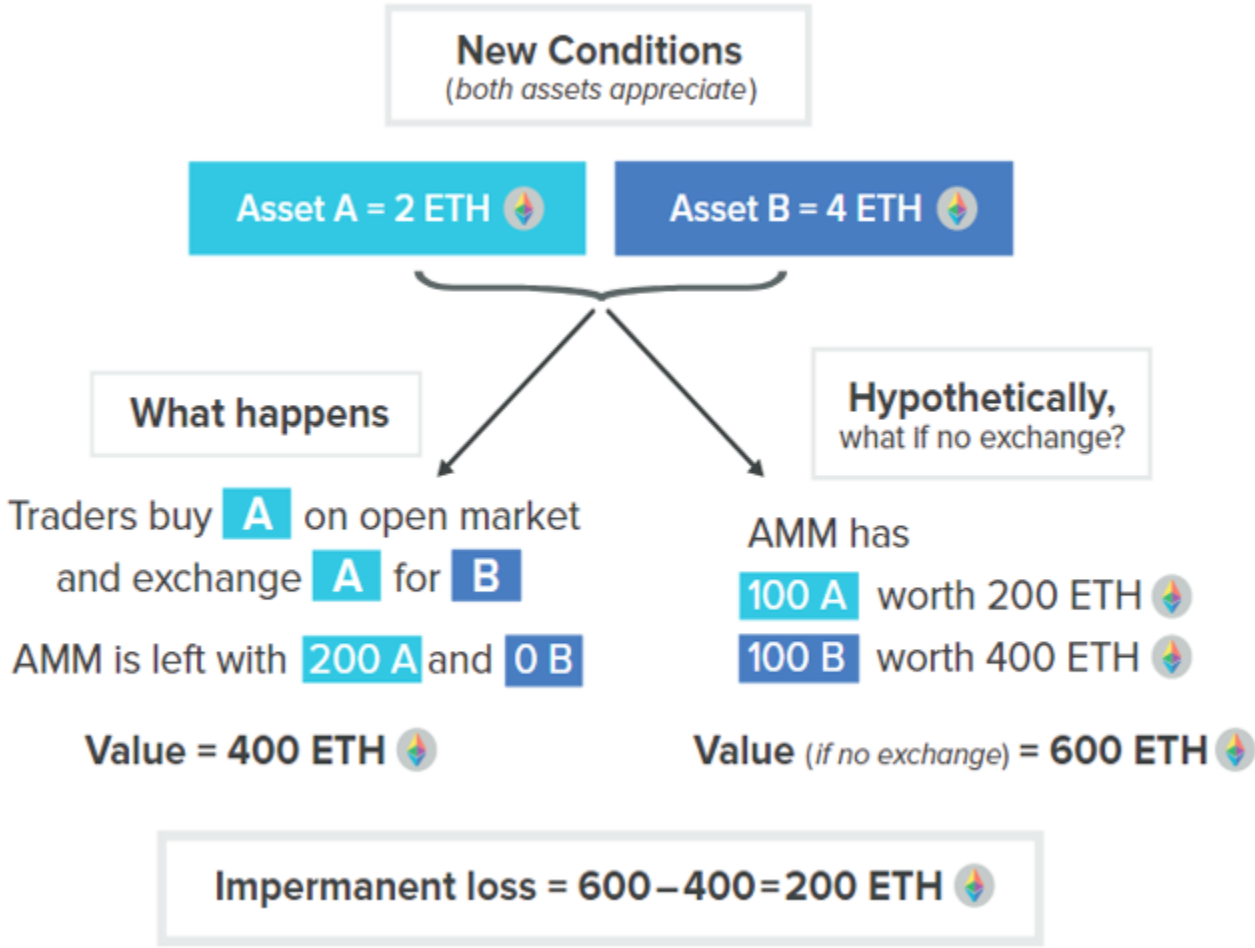
Impermanent loss example

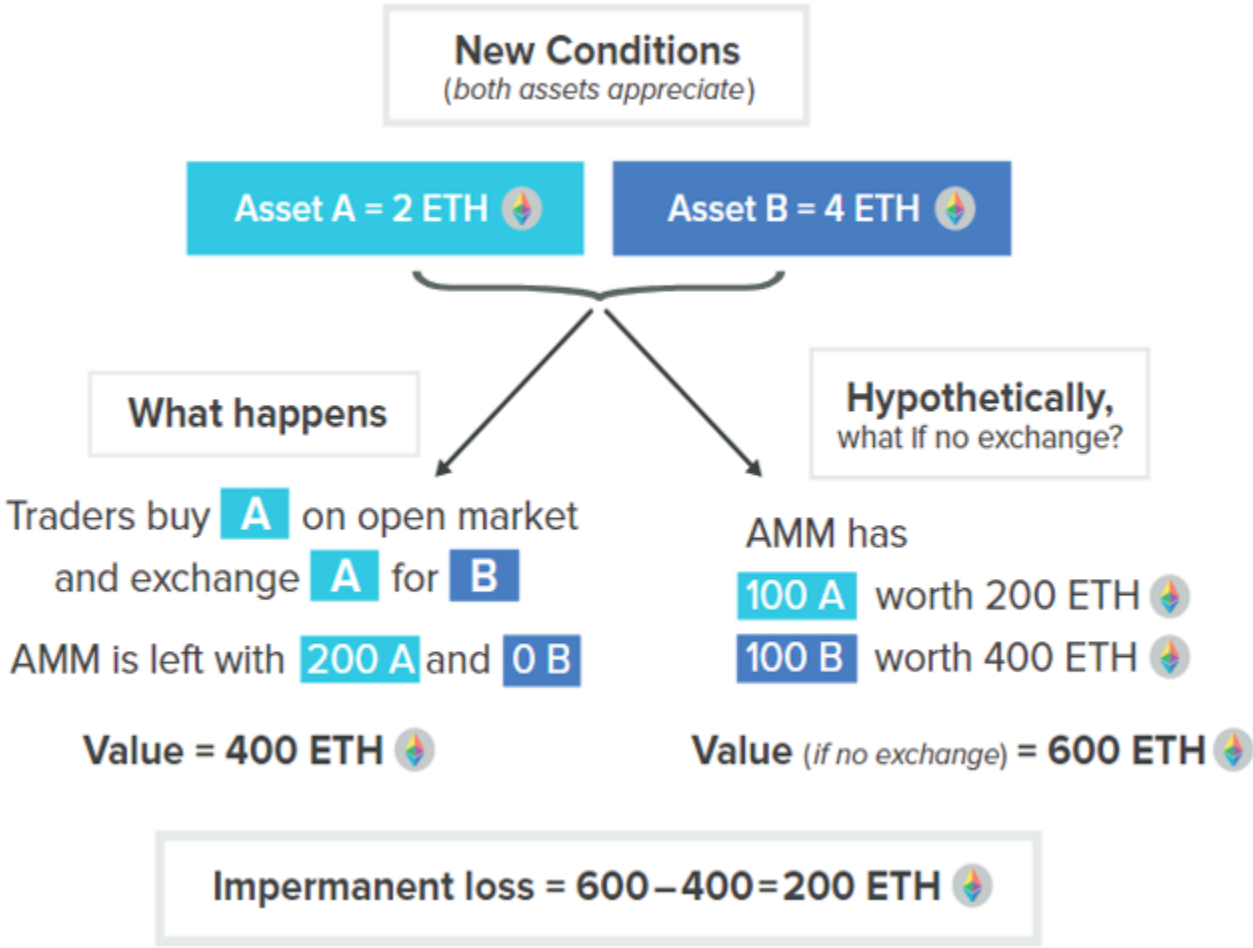
- New conditions. Both tokens appreciate in value. Now:
  - Token A = 2 ETH and
  - Token B = 4 ETH
- AMM has an exchange rate of 1:1
- Traders buy token A on open market (like Coinbase) and exchange it in the AMM for B – draining all the B.



Swap

Impermanent loss example

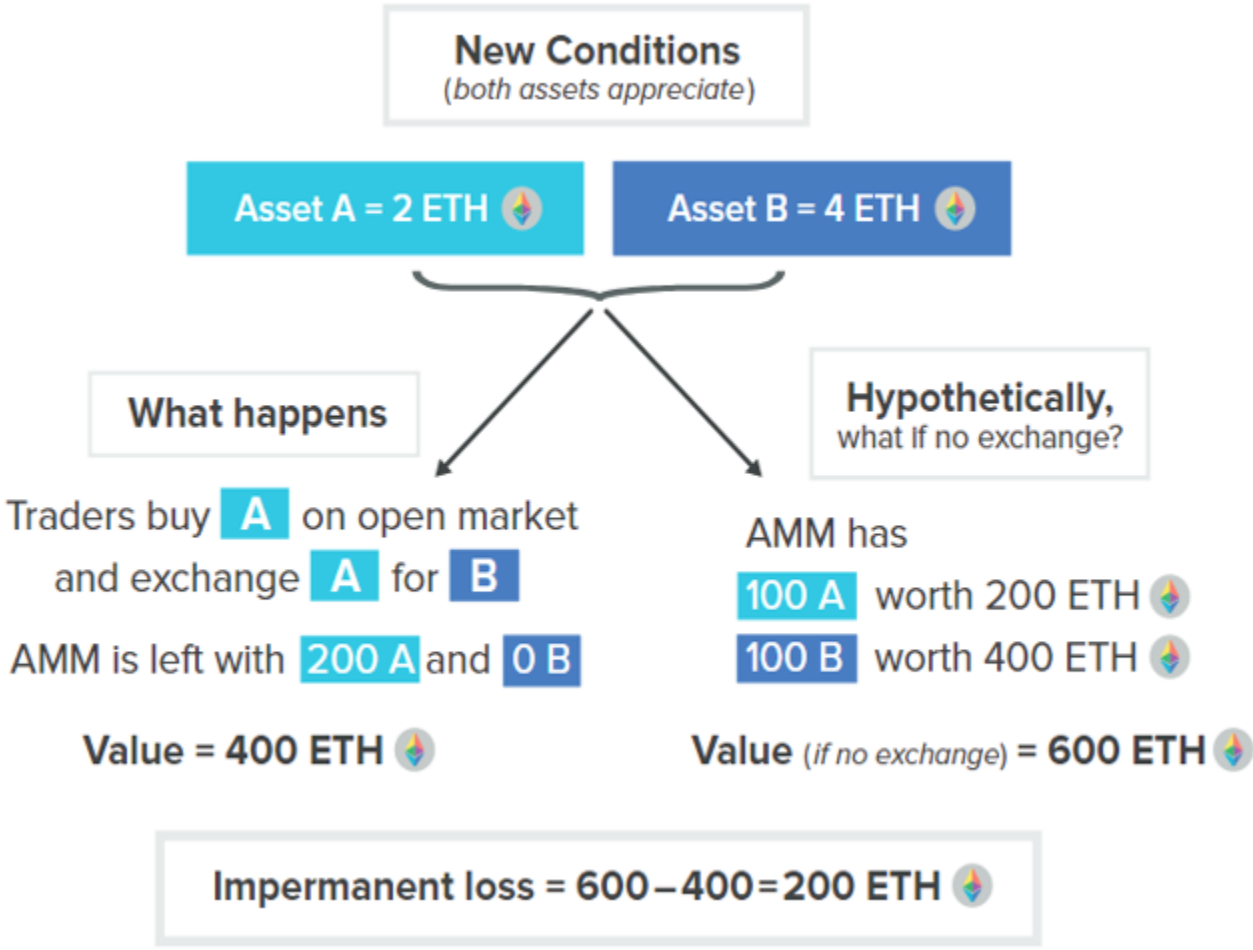
- Contract left with 200 A and zero B.
- Value = 400 ETH
- However, if there was no exchange in the AMM, the value would be 600 ETH
- Impermanent loss is the difference 600 – 400 = 200 ETH



Swap

Impermanent loss example

- This simplified example had an exchange rate of 1:1
- We will talk in greater detail about Uniswap but let me preview an example and calculate impermanent loss



https://academy.binance.com/en/articles/impermanent-loss-explained

Swap

Impermanent loss Uniswap v2

- Initial market prices are 1 ETH = 100 DAI
- Alicia deposits 1 ETH and 100 DAI into a liquidity pool
- Alicia will earn a fee for providing liquidity
- Notice that an equal value of DAI and ETH are deposited
- There are others like Alicia in the pool which has a total of 10 ETH and 1,000 DAI. The total liquidity is 10,000 = 10 x 1,000
- Alicia owns 10% of the pool

Swap

Impermanent loss Uniswap v2

- New market prices are 1 ETH = 400 DAI
- Arbitrageurs see the opportunity and buy DAI in open market and use DAI to withdraw ETH. The exchange price depends on the ratio of price whereas the liquidity (10,000) remains constant.
- Arbitrageurs will drain 5 ETH so the pool now has 5 ETH and 2,000 DAI. Notice liquidity is still 10,000 and the new ratio is 1:400 (reflecting market prices).

Swap

Impermanent loss Uniswap v2

Vault	x*y=k	k is constant	
ETH	**DAI**	**product**	**price of ETH in DAI**
10	1,000.00	10,000	100.00
9	1,111.11	10,000	123.46
8	1,250.00	10,000	156.25
7	1,428.57	10,000	204.08
6	1,666.67	10,000	277.78
5	2,000.00	10,000	400.00

Swap

Impermanent loss Uniswap v2

- Alicia owns 10% and withdraws all her funds from the pool. That will be 0.5 ETH and 200 DAI.
- USD value is $400 ($400 x 0.5 + $1 x 200)
- Her original investment was $200
- However, if she did not deposit into the pool, the value of the assets would have been $500 ($400 x 1 + $1 x 100)
- The impermanent loss is $100 ($500-$400)
- Note that there is a profit overall plus we are not accounting for the fees that Alicia would earn for providing liquidity

Swap

Impermanent loss features

- Impermanent loss occurs for any shift in price and liquidity, because the contract is structured to sell the appreciating asset and to buy the depreciating asset.
- An important feature of impermanent loss is *path independence*. In our example, it is irrelevant whether 1 or 100 traders consumed all the liquidity.
- The final exchange rate and contract asset ratios yield the same impermanent loss regardless of the number of trades or the direction of the trades.

Swap

Impermanent loss features

- Because of path independence, impermanent loss is minimized on trading pairs that have correlated prices (*mean-reverting pairs*).
- Thus, stablecoin trading pairs are particularly attractive for AMMs.