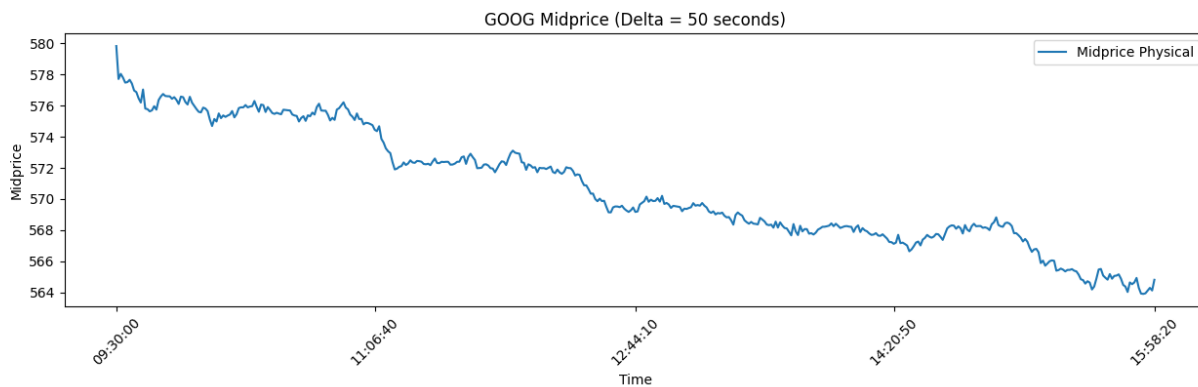
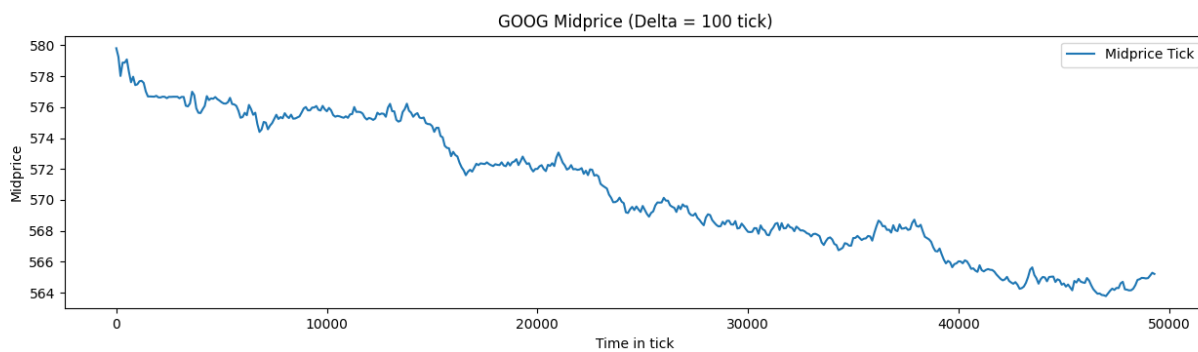
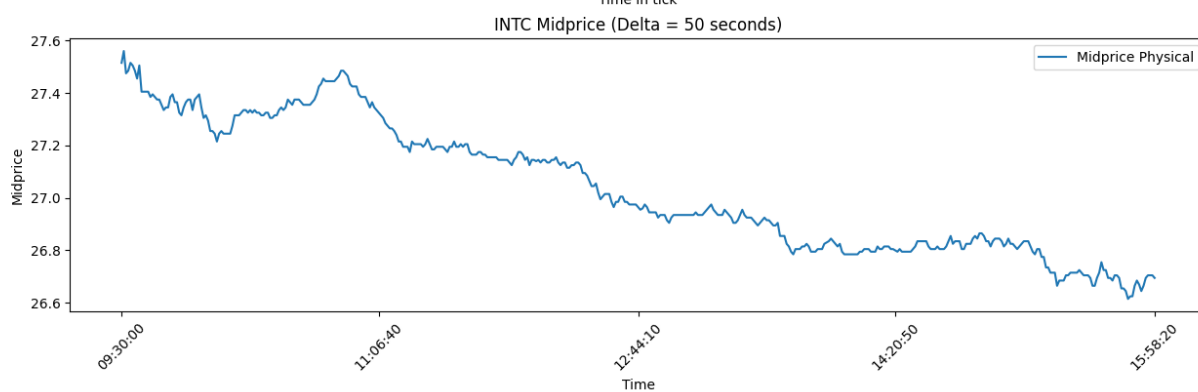
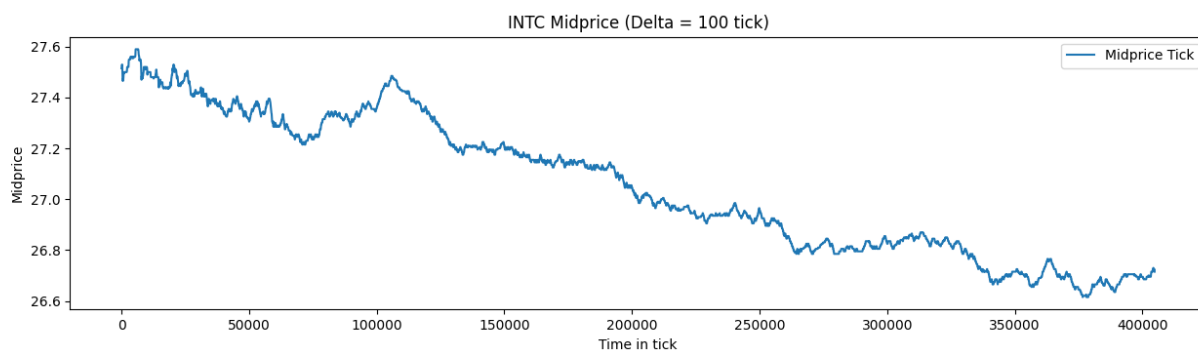
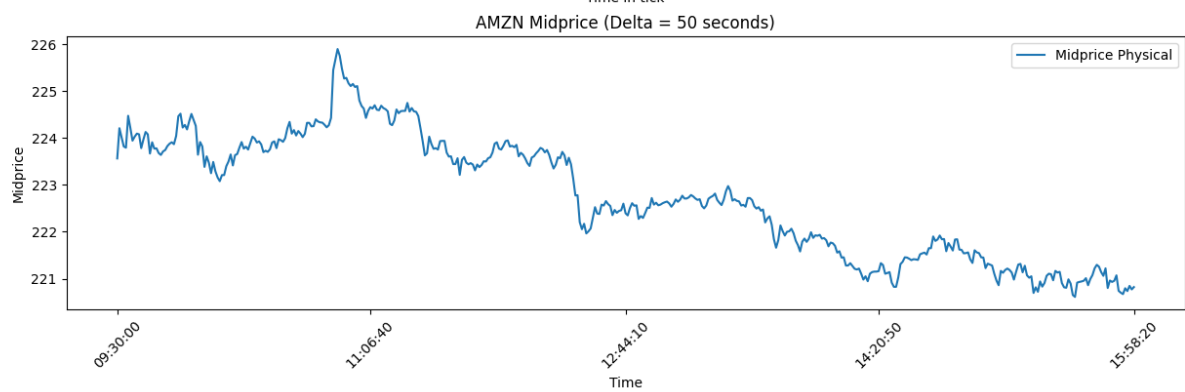
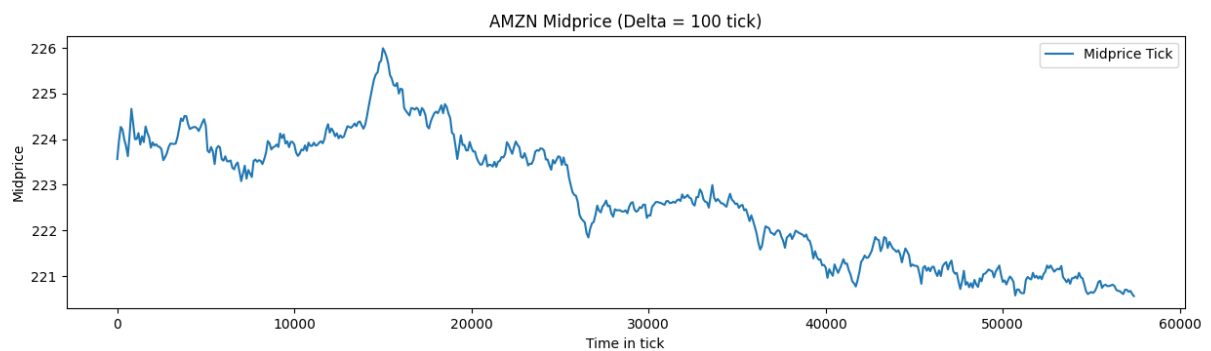
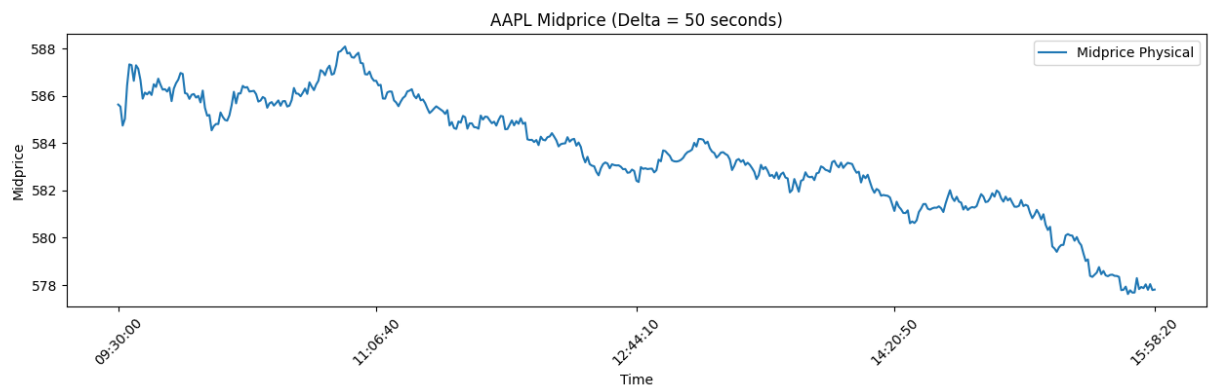
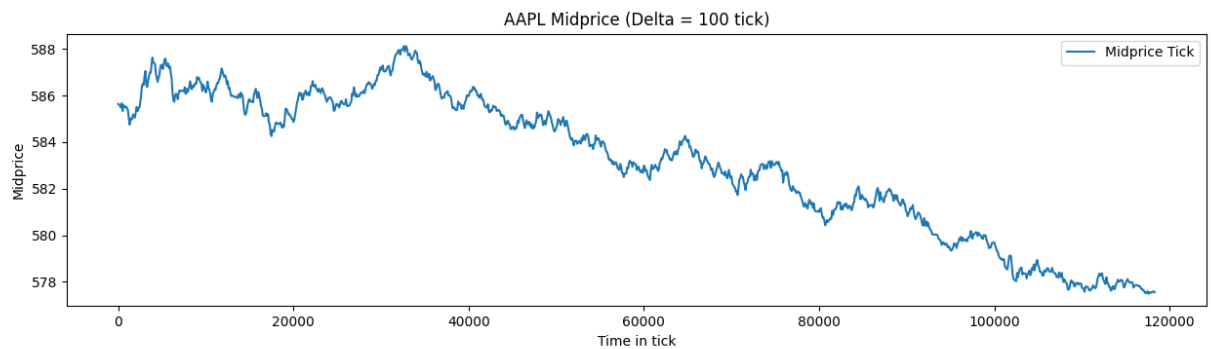


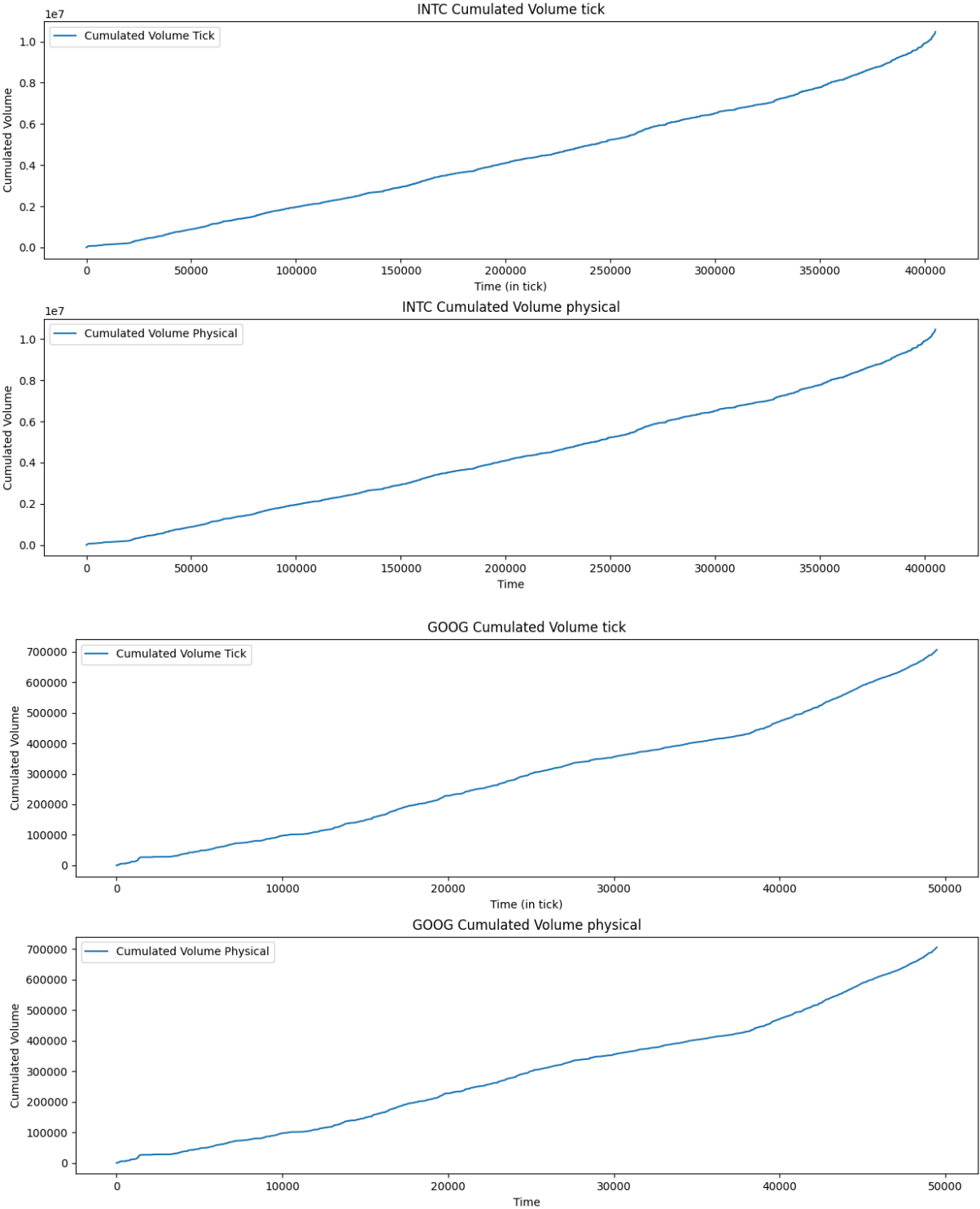
## Problem 4

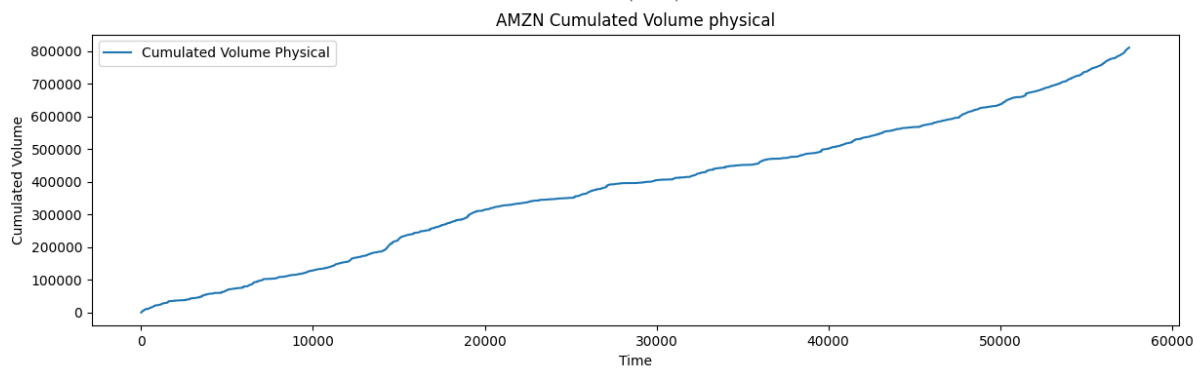
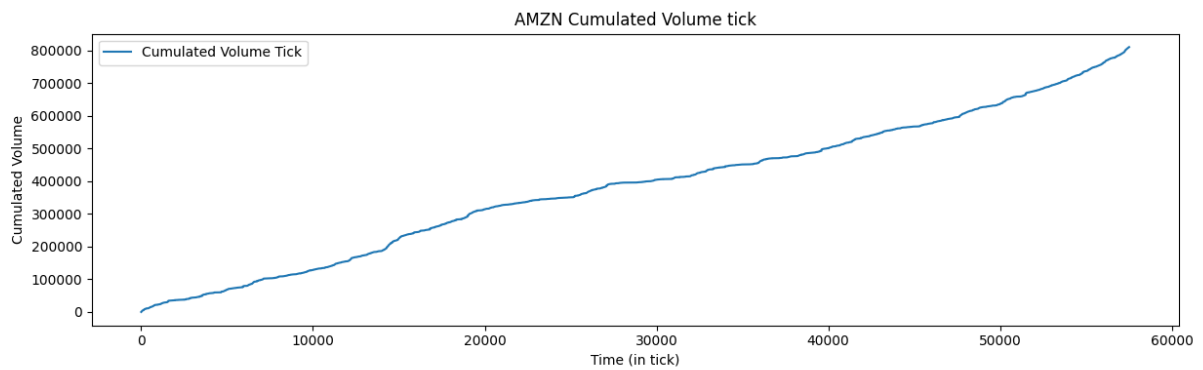
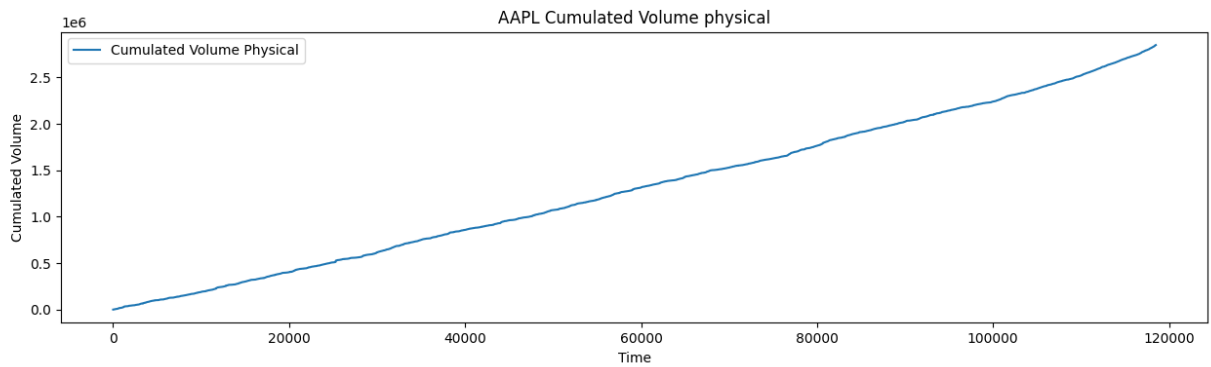
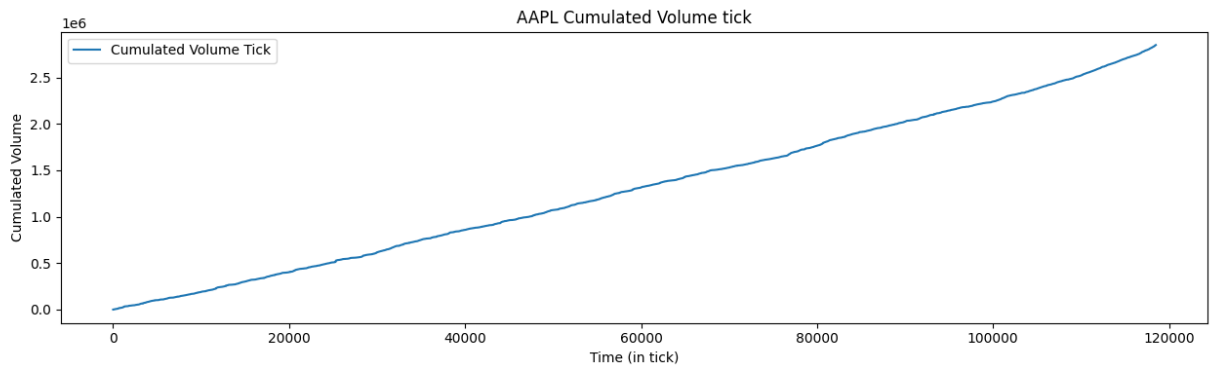
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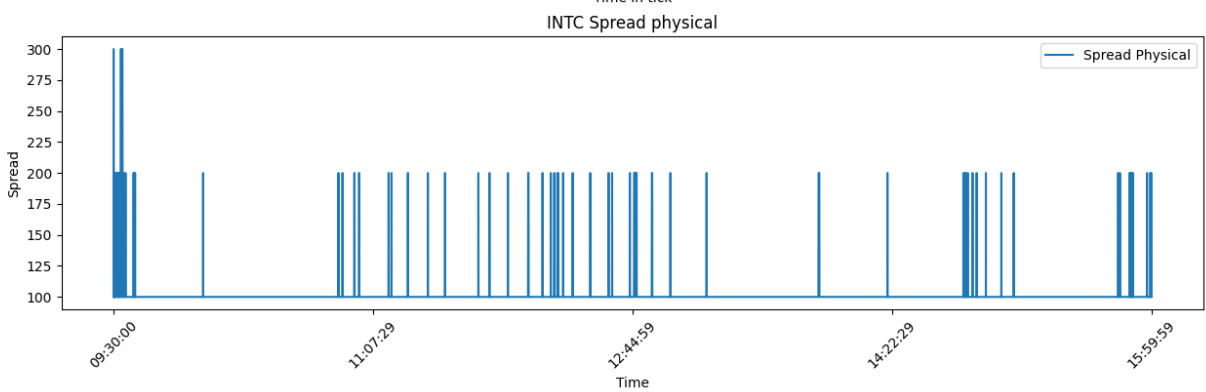
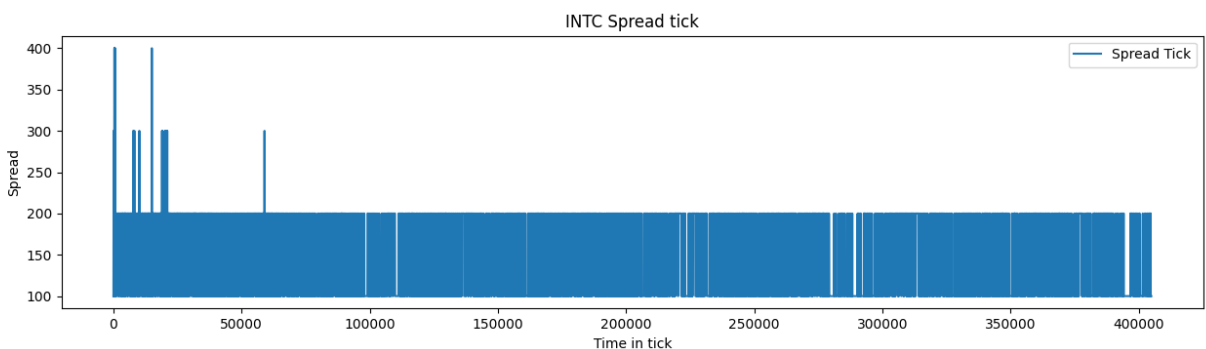
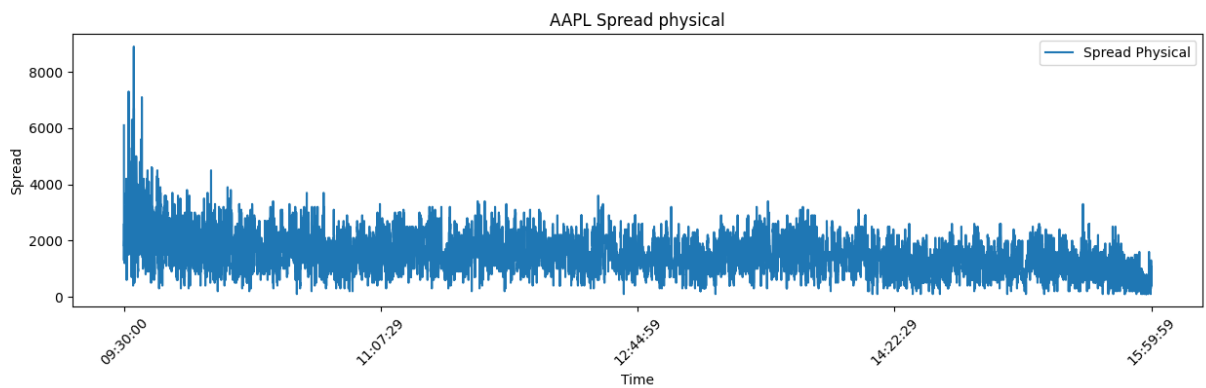
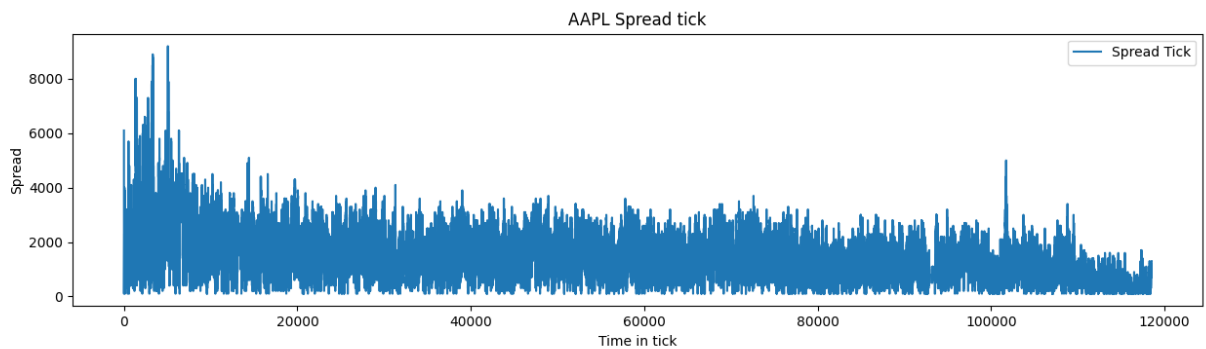


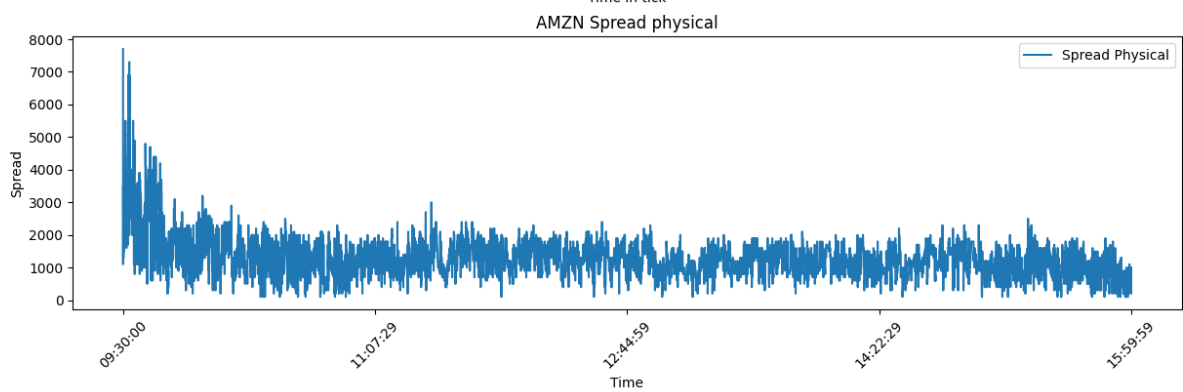
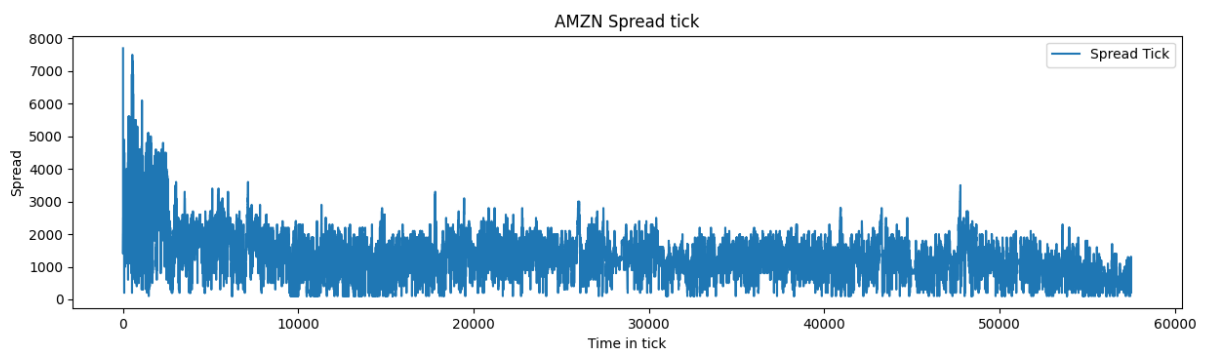
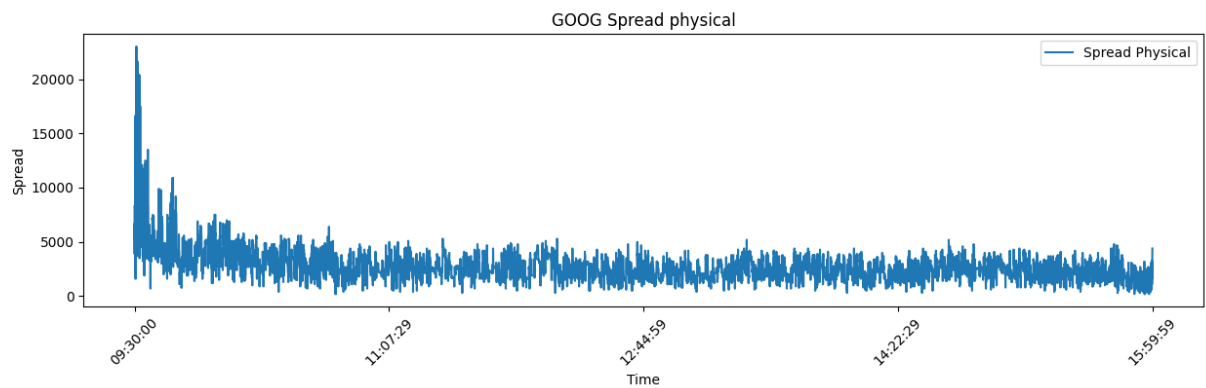
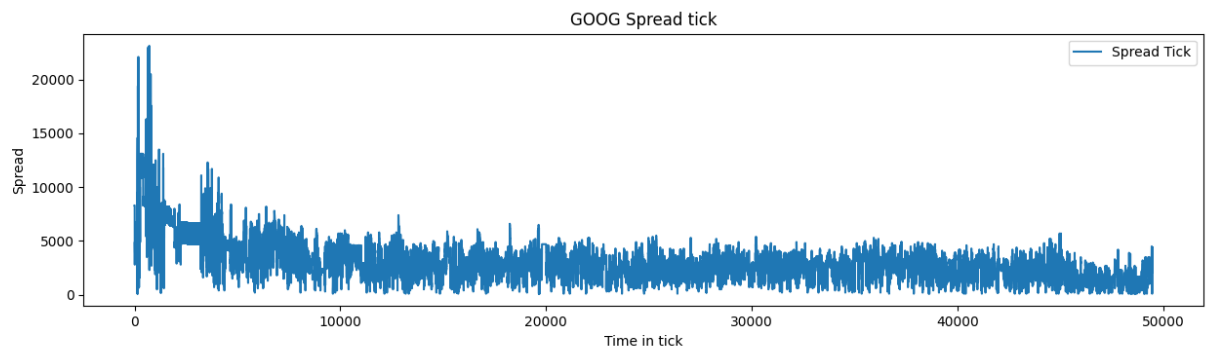
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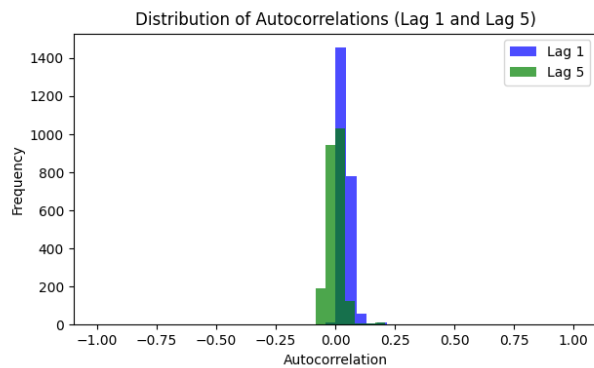
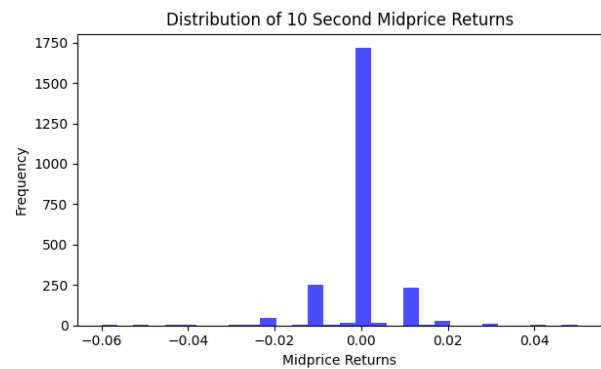
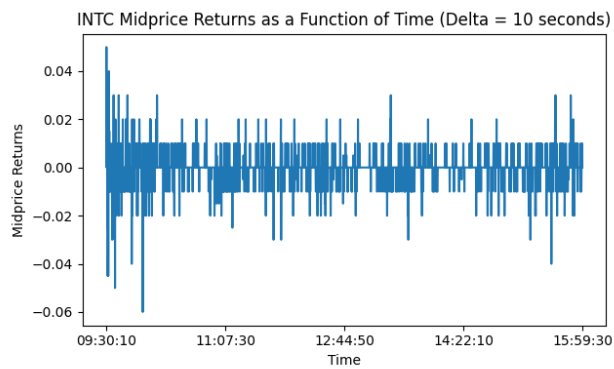
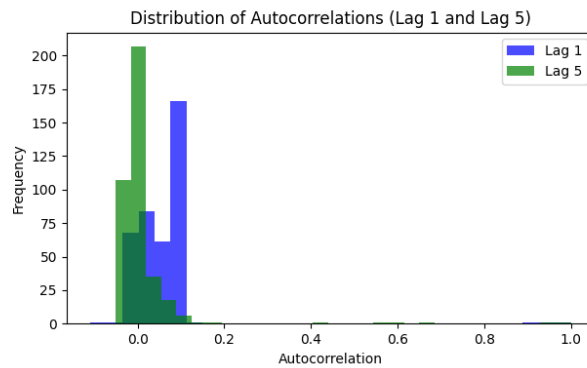
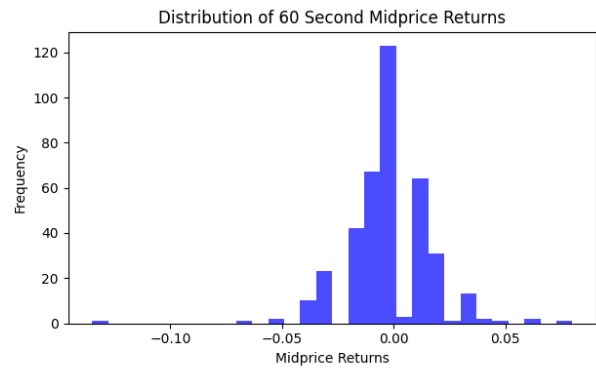
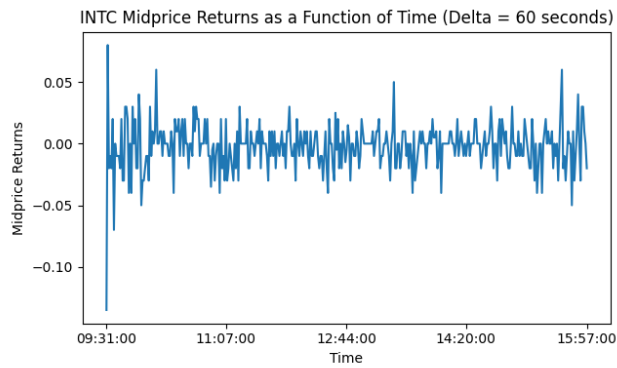


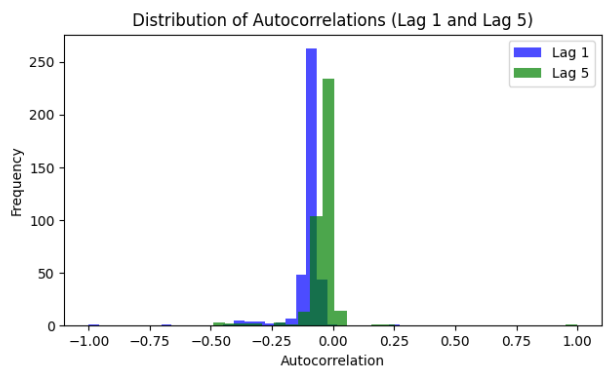
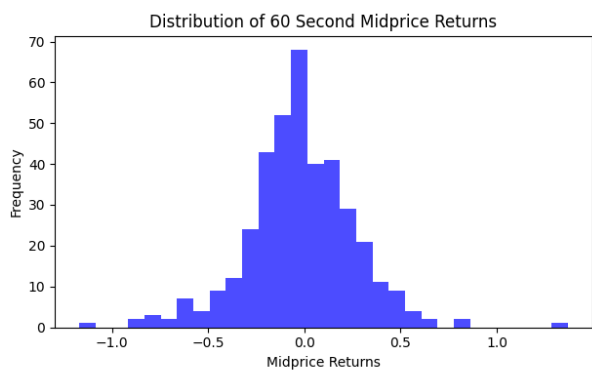
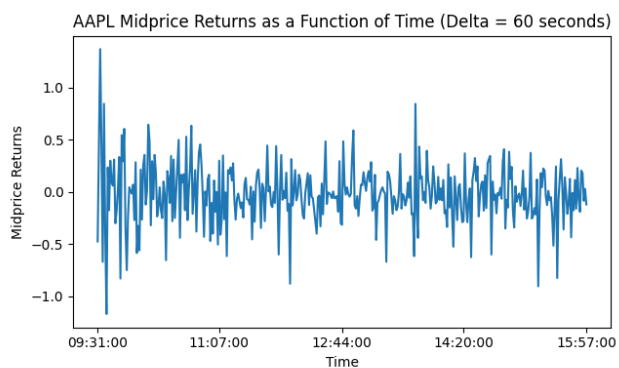
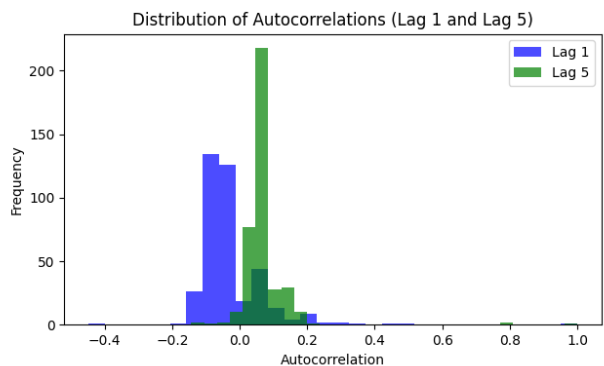
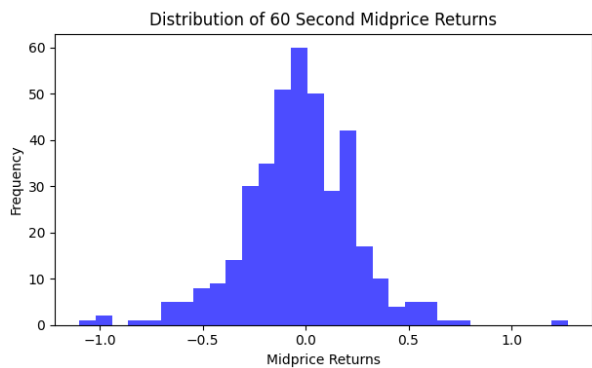
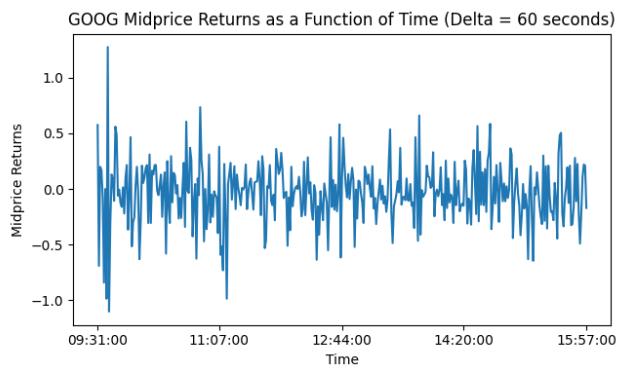
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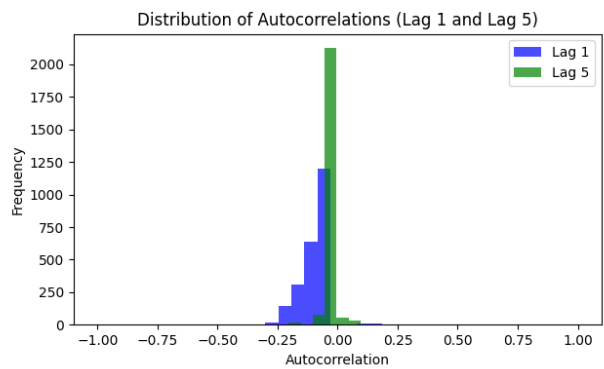
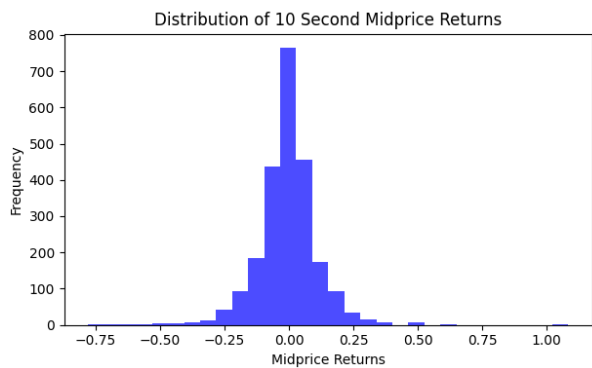
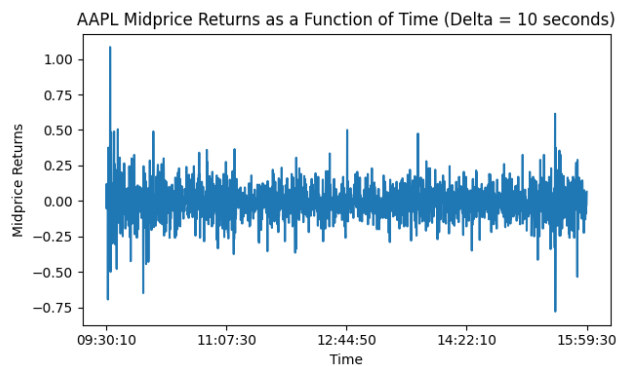


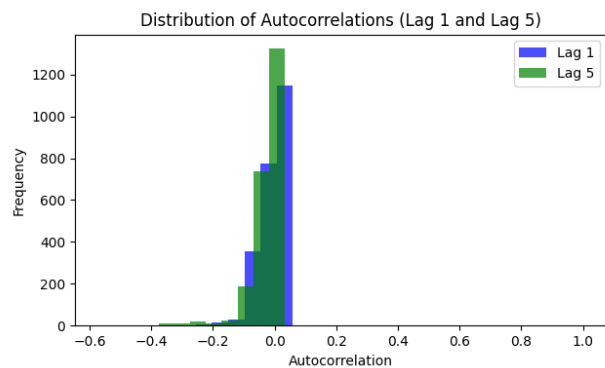
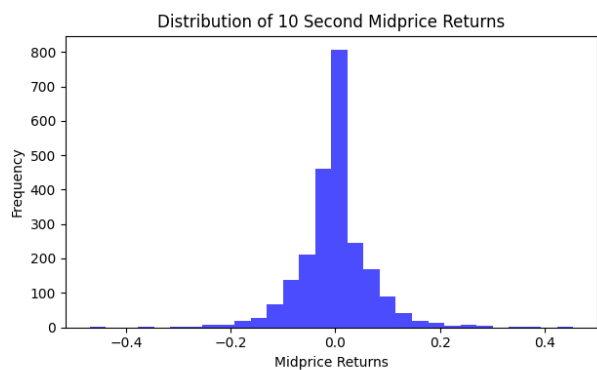
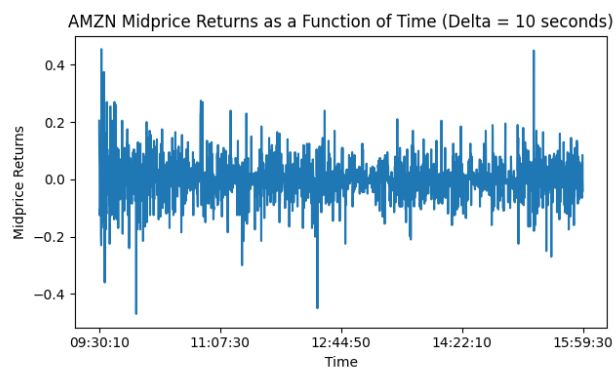
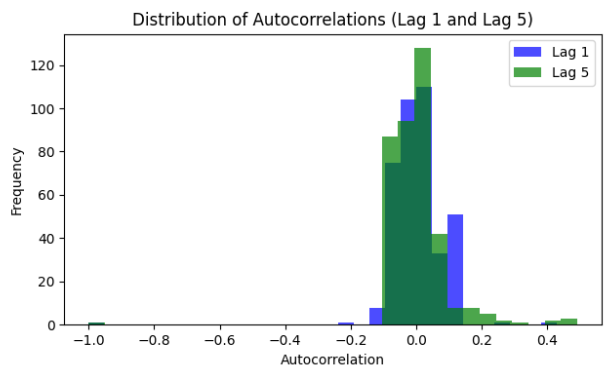
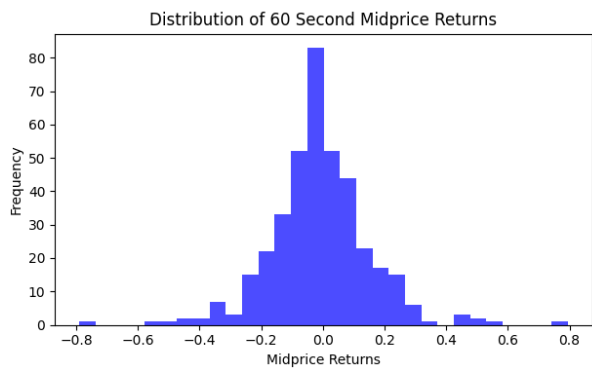
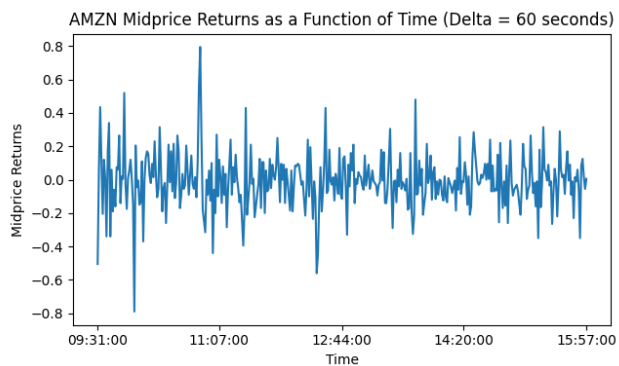
### Question d:



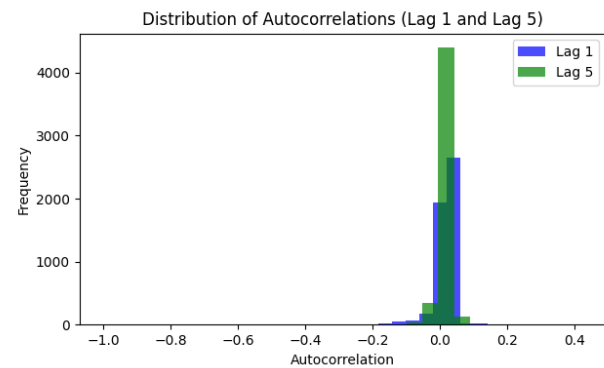
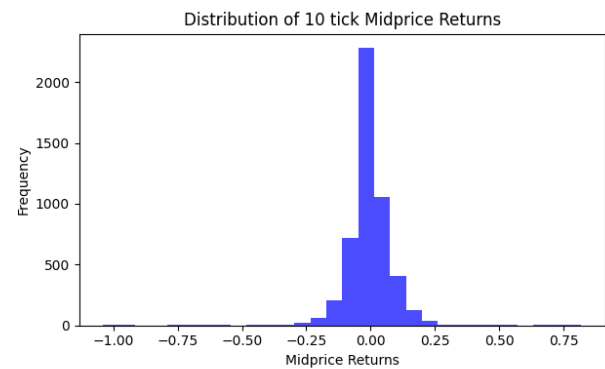
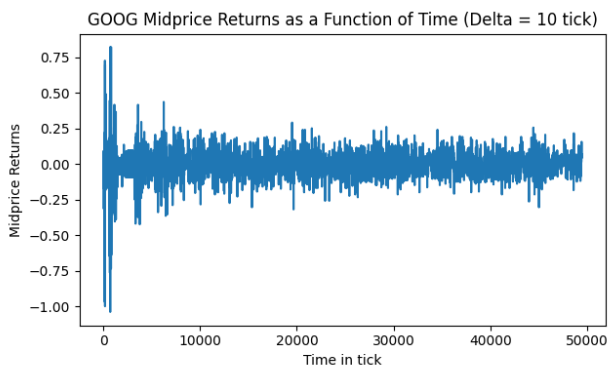
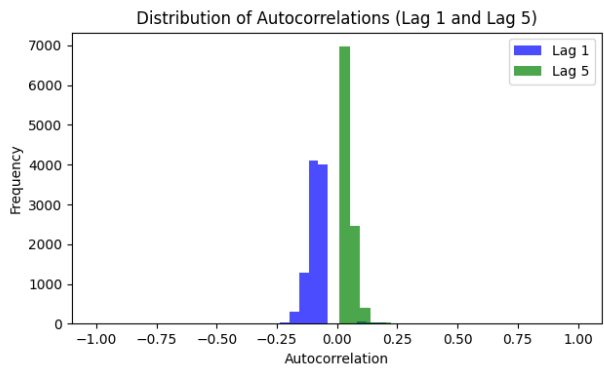
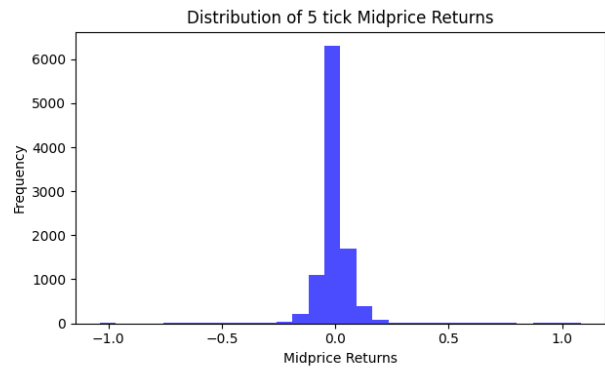
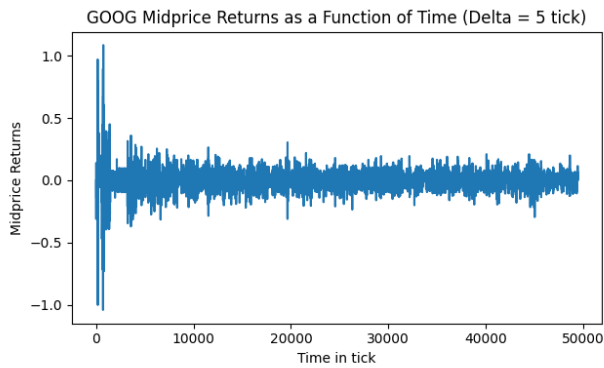


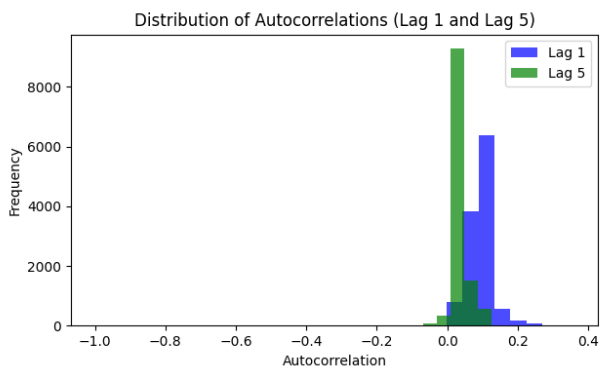
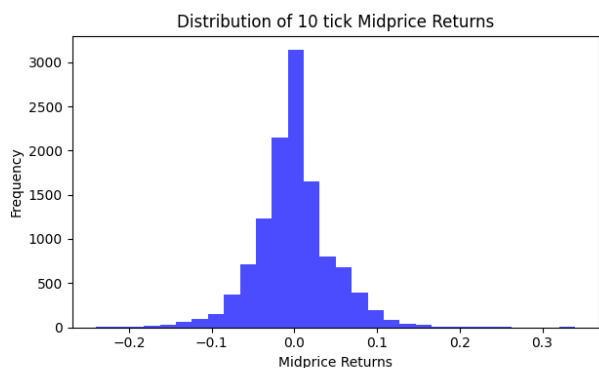
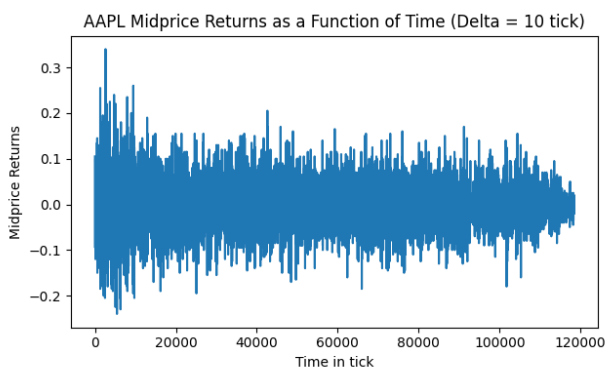
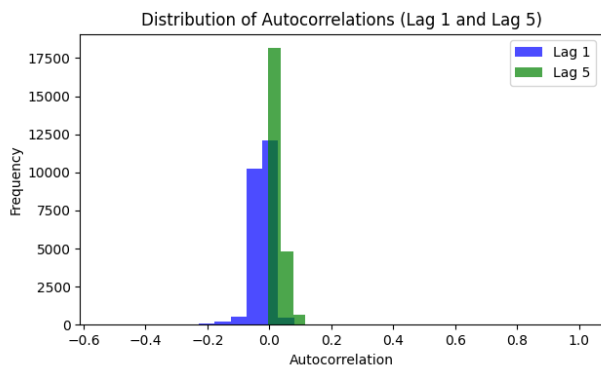
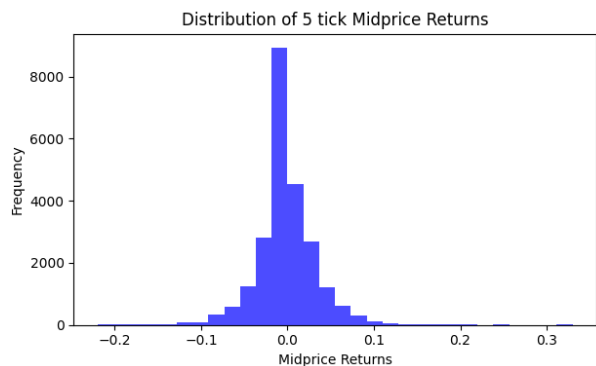
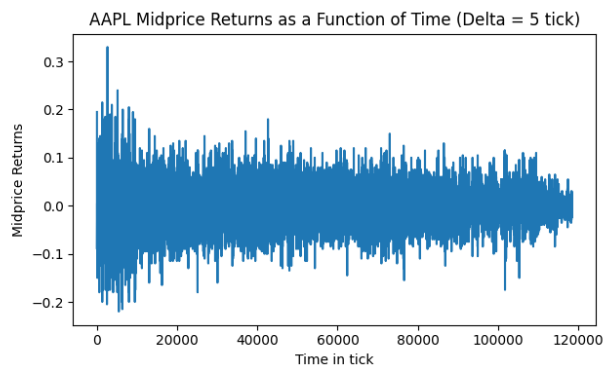


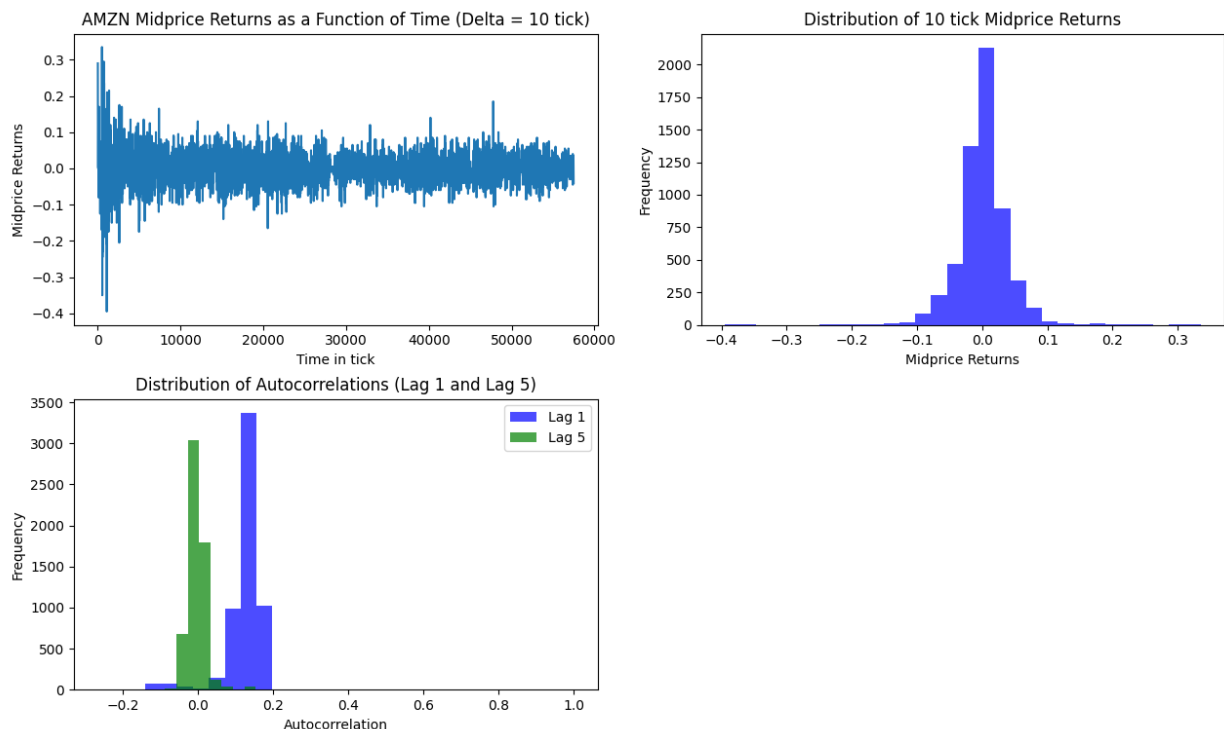




### Question e:

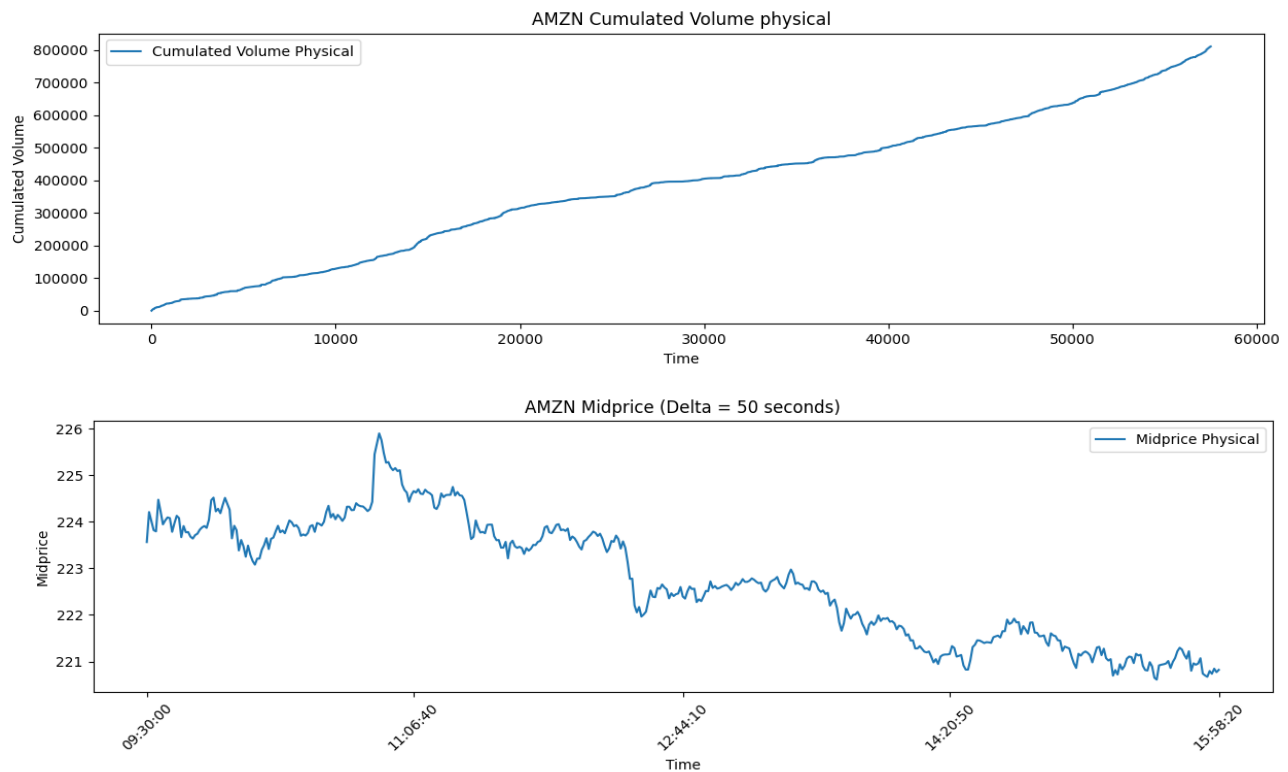






### Question f:

- "Absence of autocorrelations Linear autocorrelations  $\text{corr}(r_{t+\tau, \Delta t}, r_{t, \Delta t})$  of asset returns over periods  $\tau$  longer than 20 minutes are insignificant" We observe that the greater the delta, the more insignificant the autocorrelation is. Lag 5 is more keen to be centered on 0 than lag 1.
- "Heavy tails and aggregational normality The distribution of daily asset price returns shows fat tails; however, as one increases the period of time  $\Delta t$  over which these returns are calculated, asset returns show lower tails." We observe here on the midprice\_physical plots, that tails are fatter for a delta=1min than for a delta=10s.
- "Intermittency At any micro or macro time scale, asset price returns must display high degree of volatility." It's clearly the case here, nothing is steady.
- "Gain/loss asymmetry Gain/loss asymmetry is prevalent for equity price returns as stocks lose value faster than they grow." We can spot that specifically on the AMZN mid price plot.



- “Volume/volatility positive correlation Volume and volatility are positively correlated.”: The above graphs illustrate that during periods of high volatility, cumulative trading volumes experience rapid increases.
- “Intraday volume patterns LOB volumes are known to exhibit strong intraday patterns. In most equity markets, volumes are highest in the beginning of trading day, followed by a period of lower activity, and then spike again at the end of the trading day” An observation evident from the cumulative volume plots is that towards the end of the trading day, there is a notable and steeper increase in all the curves, particularly in the case of INTC.
- “Intraday volume/spread negative correlation Lower spreads are typically observed during periods of higher trading volumes.” On the spread plots, it becomes apparent that as trading volumes surge towards the end of the day, the spread tends to decrease.

### Question g:

I preferred working with tick time; it's much easier to code. However, it's impossible for a human to understand what is happening in tick time. Investors want results in days, months, and years, not tick time. Also, tick time is more convenient to work at the market's speed. For instance, if you're working in a very unstable market where a lot of transactions can happen within a minute, then no more transactions for an hour, working in tick time can be convenient. Anyway, if the code is supposed to interact with humans, formatted physical time is mandatory.

