Individual Assignment Overview:

For this assignment, you will learn how to optimize your portfolio with mean-variance optimization, as well as specifying additional risk constraints to reflect your market view going forward.

Your work will be mainly assessed based on whether you have fulfilled the objectives of the task. Marks will be deducted for incorrectness or missing out requirements – it is not expected that you spend a lot of time producing perfect work for this - you should get most if not all of the marks if you simply meet the requirements outlined in this assignment.

Your submission deliverables will be a PDF report and the python notebook. Each individual should submit both of these (if working in a group, it is okay that the submitted deliverables will be exactly the same – just one will be marked). Make sure all the names of the group members and the student ID is written both on the notebook and report.

Objective:
To understand and apply portfolio optimization techniques in constructing a diversified portfolio that maximizes a given metric (we will use the Sharpe Ratio for this assignment). Learning portfolio optimization is essential for maximizing investment returns relative to risk. By strategically allocating assets in a quantitatively guided approach, investors are more likely to achieve better risk diversification, as it ensures that they do not overly expose themselves to any single asset or sector. This practice leads to more robust and resilient investment portfolios, enhancing long-term financial outcomes and stability.

Tasks:

Pretend you're a fund manager looking to build a portfolio of Singapore stocks:

1) Pick at least 10 SGX stocks (max 15) you think that might do well going into the future. You can use either qualitative reasoning or quantitative techniques to help you shortlist the stocks. You may use stock screeners such as https://finance.yahoo.com/screener/new to get the list of stock tickers for the assignment. Do not spend too much time on this task – you are to write only at most half a page in discussing how you came up with the list. As long as you have a reasonable process or justification (in the case of qualitative arguments) of selecting the stocks, you should get full marks for this subtask.

2) Use yfinance to help you download the time series and organize the price data into a pandas dataframe. The dataframe should look something like this:
   We will use the data from start of 2015 to end of 2022 as our training data to train our optimizer. We keep data for 2023 as our holdout period for backtesting evaluation. It is normal that some of the stocks may have plenty of

<<NA>> values as they do not exist in the time period. Do inspect the head and/or tail of the dataframe to figure out which ones are subject to these issues. It is suggested you replace it with another stock (or initially shortlist more so you will still meet the requirement of 10 even after dropping NA series).

	XOM	RRC	BBY	MA	PFE	JPM
date						
2010-01-04	54.068794	51.300568	32.524055	22.062426	13.940202	35.175220
2010-01-05	54.279907	51.993038	33.349487	21.997149	13.741367	35.856571
2010-01-06	54.749043	51.690697	33.090542	22.081820	13.697187	36.053574
2010-01-07	54.577045	51.593170	33.616547	21.937523	13.645634	36.767757
2010-01-08	54.358093	52.597733	32.297466	21.945297	13.756095	36.677460

3) You will practice using PyPortfolioOpt, one of the most popular packages for portfolio optimization out there.
4) Install PyPortfolioOpt by using the pip command (!pip install PyPortfolioOpt will install it if running it on your notebook). Follow the first two steps on https://pyportfolioopt.readthedocs.io/en/latest/UserGuide.html - specifically, retrieve the mean and covariance by using the mean_historical_return and CovarianceShrinkage approaches. There are other approaches and they have their own pros and cons, but for the purpose of this assignment this will do.

5) Run portfolio optimization through passing the mean and covariance matrices to the EfficientFrontier function, and run the max_sharpe method. You should refer to the rest of the User Guide as per the link provided in Step 4 to achieve this. This will give you the weights that maximizes the sharpe ratio. **Please ignore the section on shorting positions – in this assignment, we will only have long positions for our stocks (the last part on improving performance is also not required, unless you wish to explore yourself)**

   Just for your own knowledge: Do note that one of the problems with Mean Variance Optimization is that it tends to produce very sparse solutions (with many weights being zero) due to possible misestimations of the "true" expected return or risk going forward – since historical returns are used to proxy for the input. Other better estimates exist (such as the CAPM return which provides for a more smoothed estimate, and in some cases, the exponentially weighted average return model may work better), and in practice people do incorporate their own forward looking estimates by using prediction models, manually adjusting them or using techniques such as Black Litterman Model to help build towards a more forward looking estimate. This is purely all for your own knowledge – if you have time, you could explore and experiment with other inbuilt functions of calculating expected returns (https://pyportfolioopt.readthedocs.io/en/latest/ExpectedReturns.html), but due to time constraints, it is not required).

   For this assignment, we will try to "fix" the issue of concentrated portfolios from MVO through specifying additional sector constraints which matches the forward

looking expectations that you may have, so you can leave it as mean historical return as per step 4.

6) You will backtest the performance through these two approaches:
   a) Using the weights, we get the daily portfolio return series everyday by simply multiplying the weights on the regular returns for each stock for the period of 2023. We compute the total portfolio return and standard deviation from this return series. (and also the sharpe ratio).

   b) Follow the section on "Post Processing Weights" in order to get the number of shares to purchase from the weights. If that does not work, you can manually come up with a logic to determine how many shares of the stock you should buy from the weights (highly encourage you use DiscreteAllocation library if possible to reduce possibility of miscalculations). You can assume you are managing a $1,000,000 portfolio for convenience.

      Compute the Portfolio Value by multiplying the number of shares with the stock prices everyday. Compute the daily portfolio return series by tracking the changes in this total Portfolio value. We compute the total portfolio return and standard deviation from this return series. (and also the sharpe ratio)

   c) What is the difference in the above two approaches? Why do they lead to different results?

7) Repeat the experiment with sector constraints. Specifically, refer to https://pyportfolioopt.readthedocs.io/en/latest/MeanVariance.html#adding-objectives-and-constraints on the section on sector constraints

   The reason you want to specify sector constraints is to ensure that the optimizer does not weight too much into a specific sector or to impose your view on certain sectors.

   You should be able to specify sector constraints this way:

```
ef = EfficientFrontier(mu, S)  # weight_bounds automatically set to (0, 1)
ef.add_sector_constraints(sector_mapper, sector_lower, sector_upper)
```

   Experiment with at least three sets of sector constraints and observe the results. Document briefly your rationale in selecting the sector constraints for each set.

   Provide some brief reasoning regarding the sectors. You should have constructed and backtested four portfolios (Base Portfolio as per Step 6 and three other portfolios where you have experimented with different constraints).

Tip: Sector constraints can be used in creative ways – beyond just mapping stocks into their traditional sectors (e.g Technology), you can think of other ways of categorization as well (e.g size, style, risk level, and so on).

Note: For the assignment, we specified you have to conduct three experiments with their own set of sector constraints – however, nothing is stopping you from specifying multiple sector constraints in each individual set.

8) Discuss the performance of the portfolios you backtested and select a suitable benchmark ETF for benchmark comparisons. (you can/should calculate various performance metrics for comparison purposes).