Optiver

Trading Interview Preparation

Optional reading on trading fundamentals

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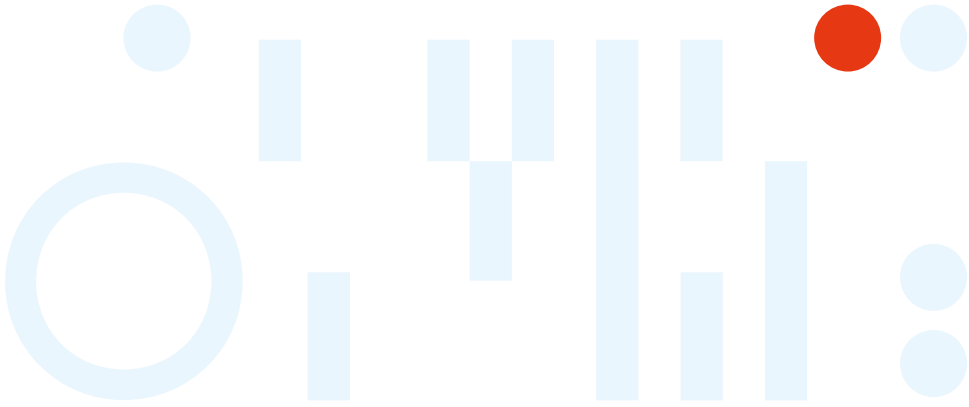

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1 Introduction

At Optiver, our mission is to improve the markets. We believe that an efficient, fair, transparent and competitive marketplace improves the health of the global economy. How do we accomplish that? We improve the overall markets by trading a variety of financial instruments using cutting-edge technology, data-driven strategies and risk-conscious decision making. Optiver is the *largest options market maker* in the world, but that is just one of the instrument classes we trade. Given the trading industry is still relatively small when compared to other careers, it can appear daunting to those without familiarity. This document's purpose is to help de-mystify some aspects of the job.

Note that *none* of this is required reading to successfully pass Optiver's interview process. We will challenge your mathematical problem solving ability and decision making, but not in a way that requires previous trading experience or knowledge of the financial industry. In fact, reading this document is entirely optional. We only wish to provide an introduction to the world of trading (along with some concepts and terminology), and perhaps dispel a few interview myths you may have heard along the way.

2 Who are we looking for?

It is a common misconception that trading requires a specific background. In fact, *you don't need to have any knowledge of financial math* to be successful in the interview. Our applicants come from a variety of STEM fields: math, engineering, actuarial science, computer science, etc. and our bespoke training program will teach you everything you need to know about product specifications, financial instrument pricing and more.

All you need is a sharp, quantitative brain, a love of solving problems and a desire to apply all of this toward improving the world's financial markets.

Bring along your curiosity. We will teach you the rest.

What sort of math do you need to know? Given that trading involves risk and reward, probability and statistics are key. The following three exercises are designed to give you a taste of the types of things we would like you to be able to think about.

Exercise 1

Two cards are pulled out from a standard deck of 52 cards. What is the probability that they have the same suit?

Exercise 2

A six-sided dice is rolled six times. What is the probability that the number six does not appear at all?

Exercise 3

Consider 100 cars all of which are traveling along a road in a randomly chosen order. At first, the cars are all traveling at distinct speeds and are sufficiently spaced out. Over time, however, some of the cars will catch up to slower ones and will also have faster cars catch up to them. When this happens, the faster car that comes up from behind must slow down. Once the cars have all settled into their clusters, how many of these clusters do you expect there to be?

Exercise 4

You and a friend are going to play a game with a $.50 coin, a $1 coin and $2 coin. You may choose one coin to be your coin. Then, all three coins will get tossed in the air. If a coin lands on tails, it counts zero for its owner. If a coin lands on heads, then it counts for its value in cents for the owner. Whoever gets the largest score wins all three coins (in the case of three tails, the toss is repeated). What coin should you choose to maximize your expected monetary win?

You do not have to be able to solve these four problems, but you should definitely feel some sort of internal pull to give them a try! This is what we look for – a *drive* to solve quantitative problems.

This could be on a computer or using pen or paper.

This also turns out to be one of the best parts about working at Optiver. Our company is full of brilliant people from different paths who have come together to work on one problem: improving the world's financial markets. We do this by providing stable, reliable and accurate pricing to the market. One mechanism you may have heard of is *market making* (we will tell you a bit more about this soon!)

3 Quantitative trading versus HFT research

Many of our applicants ask, “Am I more suited to being a Quantitative Trader or an HFT Researcher?” Both roles require a penchant for mathematical thinking and problem solving; it’s the activities and workflow that are different.

Quantitative Traders spend a good deal of their time plugged in to markets, making decisions quickly and discussing these decisions in an active environment with colleagues. They write code and build tools to automate the decision making where possible. Traders are sharp, highly intuitive and quick at engineering non-textbook approaches to new problems. They are able to influence the trades we make and the positions we take by controlling the parameters of our trading systems based on market circumstances. Our Quantitative Traders work in our Chicago office and trade on the options desks.

HFT Researchers design and deploy algorithms that are meant to operate with a higher degree of autonomy. While they still monitor these algorithms as they trade in the market, these employees generate value primarily through their project work and the iterative improvements they make to these algorithms. This project work makes up the vast majority of their time spent. They use machine learning, statistical modeling and their domain knowledge to generate features, test hypotheses and forecast future prices and develop trading strategies around them to profit. Our HFT Research team operates out of our Austin office.

The objectives of the two functions are far more similar than different. Both require curious problem solvers that design innovative solutions to complicated mathematical problems. Some domains are friendlier to AI, machine learning and complete automation (think: programming a chess engine).

Other domains are friendlier to a partnership of technology and human decision making (think of piloting an airplane). So, what role do you think fits you best? Hopefully, the above has helped to push you in the right direction. You shouldn’t stress, however; employees at Optiver are able to move between roles if they are looking for a better fit or a new challenge.

Despite the difference in the day-to-day, Quantitative Traders and HFT Researchers are both working on the problem of improving the markets. Let’s take a deeper look at how that might happen.

4 Trading basics

4.1 Market making

We all make trades every day. Buying a coffee is a trade. Selling the exercise bike you bought yourself for Christmas but never used is a trade. Waking up early to watch a game of football is a trade (you are trading sleep for entertainment).

At Optiver, we trade financial instruments. More importantly, in many cases we act as a market maker: we provide both buy and sell prices for the market participants.

Let's pretend that there is some instrument out there called X. We can plug ourselves into the exchange where X is traded and have a peek at the market. It might look something like this:

Buyers	PRICE	Sellers
	16	3
	15	2
	14	4
	13	
	12	
17	11	
5	10	
11	9	

This is called an *order-book*. In the middle column, there is a fixed list of prices that *X* can trade at. These are listed in descending order.

On the left of each price, you can see a number denoting how many units (also called lots) of *X* are desired by buyers at that price. On the right of each price, you can see the number of *X* that is wanting to be sold at that price.

So, there could be 17 different people that want to buy one lot of *X* for $11. Or it might be one single person who wants to buy 17 lots of *X*. Or it might be something in between these scenarios.

There are four lots of *X* waiting to be sold at $14. Again, this might be two different participants out there. For example, there could be one person wanting to sell one lot and another person wanting to sell three lots.

Exercise 1

Consider the order-book above. If you had to choose a single price for everyone to do their trades, what would you choose?

So, in short, there is a marketplace for *X* consisting of people who want to buy and people who want to sell. The problem? Right now, as it stands, if a buyer wants to buy then they need to pay $14. If a seller wants to sell, they will need to sell at $11.

If these trades actually take place, then some amount of *X* trades at $14 and some amount of *X* trades at $11. These are quite large swings in price. In fact, seeing these quick price changes might even deter some participants from trading as large price swings often indicate a volatile asset.

Additionally, what if somebody wanted to buy eight lots of *X*? They would have to pay up through multiple levels, buying four for $14, two for $15, and the last two for $16.

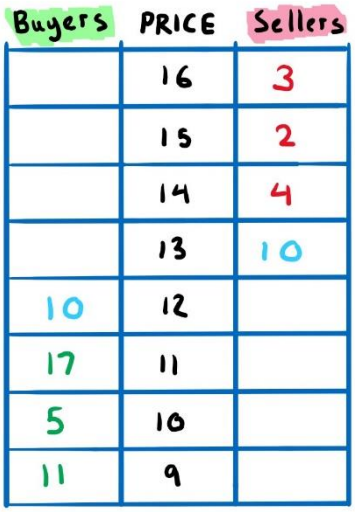
This is precisely a situation where a market maker is needed. This market is currently *illiquid.* Liquidity is a term describing how easy or difficult it is to trade a large size without affecting the price. In this example, it's quite difficult for anyone to trade for significant size without dramatically affecting the price. A trader at Optiver therefore might decide to provide some *liquidity*. By combining historical analysis, market signals, current events and any other relevant signals, our trader works out that their fair theoretical value for *X* is actually about $12.50. Theoretical value represents what you *believe* an asset to be worth.

Our trader then *makes a market* by inserting both buy and sell prices into the exchange.

Making a market involves providing both a buy and a sell price for an instrument

They insert a buy order (also called a bid) for 10 lots of *X* for $12 and a sell order (also called an offer) for 10 lots of *X* at $13. Note that neither of these orders results in a trade – *yet*. They have indicated to the market that they would be *willing* to buy X for $12 and would also be *willing* to sell X for $13.

Our trader should be pretty happy if they trade either order. They believe that *X* is worth $12.50 and is therefore happy to buy it at $12 or sell it for $13. Indeed, the trader would expect to make a theoretical profit of $.50 per lot that they trade.



Buyers	PRICE	Sellers
	16	3
	15	2
	14	4
	13	10
10	12	
17	11	
5	10	
11	9	

The market participants are happy here too. This market is now more *liquid*. A buyer can buy it immediately for $13 and a seller can sell it immediately for $12. The market is now *a fairer place* for its participants.

Notably, as the participants trade, the market maker generates profits as they buy at $12 and sell at $13 repeatedly.

4.2 Risks

There are a few risks that might spring to mind from this simple market making example.

What if a buyer immediately buys the 10 lots our trader is offering at $13? Our trader will then have a *short* position in the instrument *X*. If *X* increases in value, our trader will be losing money. Don't forget that markets can move – and quickly, too!

Exercise 2
If our trader sells 10 lots at $13, then the market moves so that they not believe the fair price for X is $17, what is their theoretical P/L (profit/loss)?

Profit or loss is calculated by comparing the current price to the traded price, then multiplying by volume. When you buy, you profit from a *rise* in the price of the asset. Thus your P/L is:

(Current Price – Purchase Price) * Volume

When you sell, your profit from a *decline* in the price of the asset. Thus your P/L is:

(Sell Price – Current Price) * Volume

In our example, our trader would have lost $40. It's not that unlikely that you might run into scenarios like this where you find it easier to sell *X* but hard to buy, or vice versa. Go back and

have a glance at the market for *X*. Something observable is at play here – demand. There actually does seem to be more buyers than sellers in this market. This can create upward pressure on *X*. A good mathematical model should likely take this into account.

Exercise 3
What other risks are involved in market making?

4.3 Position taking

After reading the previous section, it might appear that the objective of a market maker is therefore to stay flat. After all, buying and selling an equal amount of instrument X would leave our trader with no leftover risk and only profit. However, it is a misconception that a market maker's *objective* is to always remain flat.

Exercise 4
What if our trader thought that the fair theoretical value for X is $17? What should their market be?

Sometimes, you might encounter a scenario like this where you disagree with others in the market about what the fair value should be. Trading involves predicting the future, and different market participants use different models, information and features to create predictions. If your theoretical value is quite different from other people, it can be tricky to navigate. This is not all of the possible tactics you could use, but here you might consider:

- Buying X for $14 from the participants willing to sell there
- Inserting a bid for $13 instead of $12
- Inserting a bid for $12, but not inserting an offer at $13

Each of these routes has its own advantages and disadvantages. Thinking through the best strategy is often one of the most challenging parts of trading. In all cases though, your objective is not to buy and sell equal amounts of X, but just to buy because you believe the price of X will rise. When you actively seek to buy or sell without trying to do an offsetting trade, we call that *position taking*.

4.4 Fermi market making

Optiver's focus is on improving financial markets, but good practice can actually be developed by making markets on the solutions to *Fermi problems*.

These are named after the physicist Enrico Fermi, who was quite fond of estimating unknown quantities with little information. The most striking example of this is the time he dropped some

paper at a (safe) distance from an atomic blast and used the distance the paper traveled (quite accurately!) to estimate the energy released from the bomb.

Have a go at the following Fermi problem as a warm-up.

Exercise 5
How many people are on an airplane in the sky right now?

In this section, we will consider the act of making a market on a Fermi problem. Let's say that a friend of yours taps you on the shoulder and gives you the following seemingly strange request:

Make me a market on the perimeter of Tasmania.

Let's unpack this a bit. The perimeter of Tasmania is the total length of the boundary. Your friend wants you to provide a buy and sell price on this length.

A more thorough explanation might be:

I want you to give me two numbers B and S. The first number B is your buy price, and this should be below what you think the perimeter of Tasmania is. The second number S is your sell price, and this should be above what you think the perimeter of Tasmania is.

OK, it's getting clearer. Your friend is trying to get you to come up with an estimate of this distance, but she doesn't want your estimate. She just wants two numbers on either side of it.

You think for a bit. After a while you come up with an estimate of about 1200KM. You then jump 400KM each way from your estimate and tell your friend that you have chosen $B = 800KM$ and $S = 1600KM$.

Congratulations – you have just made a market. If your friend thinks that the true answer is less than 800KM, then she will sell you 800KM. After all, you have shown her a buy price there, so she is well within her rights to do this! On the other hand, if she thinks the answer is greater than 1600KM, then she will buy this from you.

Your friend opens her mouth and says:

I will buy 1600KM from you.

You and your friend have just done a trade! She has bought "the perimeter of Tasmania" from you at the price of 1600KM.

Note that you should both be happy with your trades. You have sold at a price of 1600KM when you believe the answer to be around 1200KM. Your friend has bought at a price of 1600KM when she believes the answer to be greater than 1600KM.

Of course, only one of you can be correct. Let's proceed to *settlement*; this is where the solution to our Fermi problem is revealed. In this case, a quick check on Google gives the (approximate) answer of 1400KM.

You sold at a price of 1600KM and the thing you sold settled at 1400KM. Therefore, you have made a profit of 200KM. Your friend has made a loss of 200KM.

Note: It certainly seems odd to talk about profits in terms of kilometers. If you and your friend had done this properly, you likely would have agreed upon some conversion rate (example: $1 per 10KM).

4.5 Markets and confidence

Suppose I ask you to make me markets on the following:

- The world record for the longest distance (in meters) a golf ball has been thrown
- The total number of words in all seven of the (English) Harry Potter books
- The probability that two randomly chosen positive integers have no factors in common

In each case, you first need to come up with an estimate. And not only that, but your estimates must be sane. If you say that the world record for the golf ball throw is 2KM or you say that the total number of words in all seven of the Harry Potter books is 400, then something is clearly wrong.

Once you come up with an estimate or *fair value*, you need to provide your buy price, *B,* and sell price, *S*. But how to pick these?

If you think that the world record for the golf ball throw is 150M, then here are two possible markets you might provide:

Market 1:	***B* = 0M**	***S* = 300M**
Market 2:	***B* = 149M**	***S* = 151M**

Neither of these is great. Consider walking into a room (or the Optiver trading floor) where everyone wants to trade on the world record for the longest distance a golf ball has been thrown. In fact, they have been waiting for a market maker like you to provide them with liquidity!

If you announce Market 1 to everybody, you will likely do zero trades. Nobody out there wants to sell 0M. Maybe a couple of people will buy 300M. But really, your market is *too wide*, and as such does not provide any real liquidity.

On the other hand, if you announce Market 2, you will probably do a lot of trades! If someone thinks that the answer is smaller than 149M or larger than 151M then they will trade with you. This is going to encapsulate basically everyone in the room. So, well done: you've provided some real liquidity! The problem is risk.

The ideal situation with Market 2 is that half the people in the room sell you 149M and the other half of the room buy 151M. You neatly offset every buy with a sell and you generate profit (assuming you agreed on a settlement conversion rate). Every buy that *you* have done at 149m is neatly covered with a sell that *you* have done at 151M. You make a profit of 2M (the width of your market) for every buy-sell pair.

However, as your (*B, S*) interval is so *tight*, it is much more likely that the consensus of the room falls to the side of your interval. To put some numbers to it, let's say that there are 10 people in the room and that four of them sell to you and the other six buy from you.

Your four buys at 149M pair up nicely with four of your sells at 151M. These eight trades get you a profit of 4 × 2m = 8m. But there are two more sells that you have done at 151M that you have not covered on the buy side.

If the answer turns out to be 180M, then you will lose 29M on each of these sells at 151M. These losses massively override your profits and your golf-ball market making career is sadly over.

The above example demonstrates why Market 2 is not great. The amount that you are *getting paid to trade* (a function of your width) is too small relative to the uncertainty in the underlying value.

The width of your market should be related to the uncertainty of the thing you are trading

Sometimes, we have information, and this should change our market. Also, perhaps we are constrained in some way.

Think about different information and constraints and how these can affect the width and position of your market.

To end this section, have a think about the following scenario.

Exercise 6

What if you had walked into the trading room late in the proceedings and watched for a little bit?

Let's say you just saw trading happen at these prices, in this order:

149*M*,152*M*,160*M*,155*M*,150*M*,149*M*,153*M*,158*M*.

What market would you make?

5 Conclusion

As you can see, trading at its core is quantitative decision making. Your job is to predict the future and devise a strategy under uncertainty. During the interview, your intellectual curiosity and approach you take to problem solving are weighed heavily. A sound decision might suffer an unlucky result, and a poor decision can sometimes get lucky. Whenever possible, we encourage you to think out loud and talk through your process. We hope you found this valuable. Best of luck!