Financial Engineering Interview Questions (Part I)

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Hello everyone, I am Mehul Mehta. To answer your question who is this guy? A little about myself. I completed my Masters in Financial Mathematics at North Carolina State University (NCSU) and prior to that, I worked at PwC India for ~ 3 years in their Analytics department.

I am sharing the common list of technical questions I was asked during my interview. I was targeting Credit Risk, Market Risk, Quantitative Modeling, and Financial Engineering (ABS, MBS, etc.,) kinds of roles. I was selected for various interviews and could convert 6 full-time offers (Citi, TD Securities, Moody's, Regions, etc.,).

My main motive for circulating this pdf is to help students and professionals who are interviewing for the above-mentioned roles. If you have any questions about the interview process, do reach out to me on my LinkedIn profile and I would be happy to help you out.

I wish you All the Best in your interview preparation…. !!!

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Note: I have taken the answers from different websites and are not my own.

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1. Define Value at Risk (VaR)?

Value at risk (VaR) is defined as the extent of possible financial losses within a firm, portfolio, or position over a specific time frame against a given confidence interval. Risk managers use VaR to understand and control the level of risk exposure to a specific positions or whole portfolios and use them to measure firm-wide risk exposure.

To conclude, the key elements of Value at Risk are:

a) Time period over which the risk is assessed
b) Confidence interval

2. What are the different ways to calculate Value at Risk (VaR)?

There are three major methodologies for calculating VaR.

a) Variance Covariance (Parametric Method)
b) Monte Carlo Method
c) Historical Method

Brief description and use of each approach:

Type	Description	Use
Parametric	Estimate VaR with equation that specifies parameters (for example, volatility and correlation) as input.	Accurate for traditional assets and linear derivatives, but less accurate for nonlinear derivatives.
Monte Carlo	Estimate VaR by simulating random scenarios and revaluing in the portfolio.	Appropriate for all types of instruments, linear or nonlinear.
Historical	Estimates VaR by reliving history; we take actual.	

Note: *Details of each method, advantages and dis-advantages are listed in the upcoming questions.*

3. What are the advantages of using Value at Risk (VaR)?

- **Applicability:** VaR can be applied to all types of assets, including shares, bonds, currencies, derivatives, and more. Banks and financial institutions can use this statistical measure to ascertain the risk in different investments and then allocate risk on the basis of VAR.

- **Easy to understand:** VAR value is a single digit, either as a percentage or in dollar terms. This makes it easy to understand and interpret. Finance experts use this measure widely. Moreover, it plays an important role in decision-making as well.

- **Universal:** The Value at Risk figure is widely used, so it is an accepted standard in buying, selling, or recommending assets.

4. What are the limitations of using Value at Risk (VaR)?

Value At Risk is a widely used risk management tool, popular especially with banks and big financial institutions. There are valid reasons for its popularity but there are few shortcomings.

- **Difficult to calculate for large portfolios:** When you're calculating Value At Risk of a portfolio, you need to measure or estimate not only the return and volatility of individual assets, but also the correlations between them. With growing number and diversity of positions in the portfolio, the difficulty (and cost) of this task grows exponentially.

- **VAR is not additive:** The fact that correlations between individual risk factors enter the VAR calculation is also the reason why Value At Risk is not simply additive. The VAR of a portfolio containing assets A and B does not equal the sum of VAR of asset A and VAR of asset B.

- **Different VAR methods lead to different results:** There are several alternative and very different approaches which all eventually lead to a number called Value at Risk: variance-covariance parametric, the Historical VAR method, and the Monte Carlo VAR approach. Having a wide range of choices is useful, as different approaches are suitable for different types of situations. However, different approaches lead to very different results with the same portfolio, so which VAR result should we follow?

- **VaR can give misleading results if the assumptions are not met:** To calculate VAR, one needs to make a few assumptions. If these assumptions are not valid, then the VAR figure is inaccurate as well. Just for instance, in the **variance covariance** method of VaR, the method assumes that the asset returns are normally distributed around the mean of the bell-shaped probability distribution. However, we know that asset doesn't follow normal distribution and due to this we might understate or overstate the VaR numbers which might result in under hedging or over hedging.

- **VAR does not measure worst case loss:** 99% percent VAR really means that in 1% of cases (that would be 2-3 trading days in a year with daily VAR) the loss is expected to be greater than the VAR amount. Value At Risk does not say anything about the size of losses within this 1% of trading days and by no means does it say anything about the maximum possible loss. You simply don't know your maximum possible loss by looking only at VAR. It is the single most important and most frequently ignored limitation of Value At Risk.

5. What is the parametric method of calculating VaR? State its assumptions?

The parametric approach uses the data (as an excuse) to find a distribution, usually a normal distribution which requires only two parameters: the mean and the standard deviation.

The parametric method is also known as the *variance-covariance method*. For calculating VaR, two factors are to be estimated – *an expected return and a standard deviation.* The parametric

method is best suited to risk measurement problems where the distributions are known and reliably estimated.

Assumptions

The variance-covariance method assumes that returns of the assets are normally distributed around the mean of the bell-shaped probability distribution. Secondly, it assumes that the standard deviation of asset returns and the correlations between asset returns are constant over time.

6. What is the non-parametric approach of calculating VaR?

The nonparametric approach uses actual historical data, it is simple and easy to use. There is no hypothesis about the distribution of the data. There are 2 methods of calculating VaR using the non-parametric approach that are *monte carlo and historical method.*

7. What is the historical method of calculating VaR? What are its advantages and disadvantages?

The historical method simply re-organizes actual historical returns, putting them in order from worst to best. It then assumes that history will repeat itself, from a risk perspective.

Advantages:

- One advantage of historical VaR is that it is extremely simple to calculate.
- Another advantage is that it is easy to explain to non-risk professionals.
- Accurate for non-linear instruments.
- No need to make distributional assumptions.
- The historical approach is non-parametric. We have not made any assumptions about the distribution of historical returns.

Disadvantages:

- One disadvantage of the historical simulation approach is that it can be very slow to react to changing market environments.

8. What is the Monte Carlo method of calculating VaR? What are its advantages and disadvantages?

Computing VaR with Monte Carlo Simulations is very similar to Historical Simulations. The main difference lies in the first step of the algorithm – instead of using the historical data for the price (or returns) of the asset and assuming that this return (or price) can re-occur in the next time interval, we generate a random number (Using Geometric Brownian Motion) that will be used to estimate the return (or price) of the asset at the end of the analysis horizon.

Advantages:

- Accurate for non-linear instruments.
- No need to make distributional assumptions.

- The problem with looking to history alone is that it represents, in effect, just one roll, or probable outcome, which may or may not be applicable in the future. A Monte Carlo simulation considers a wide range of possibilities and helps us reduce uncertainty.
- A Monte Carlo simulation is very flexible; it allows us to vary risk assumptions under all parameters and thus model a range of possible outcomes. One can compare multiple future outcomes and customize the model to various assets and portfolios under review.

Disadvantages:

- On the downside, the simulation is limited in that it can't account for bear markets, recessions, or any other kind of financial crisis that might impact potential results.
- If you don't know the values of variables that goes in the pricing model (GBM), then the model won't perform well.
- Takes a lot of computational power (and hence a longer time to estimate results).

9. What is non-Linear VaR? How would you calculate it?

There are two types of risk exposure: linear and nonlinear.

- Nonlinear derivatives are those whose payoffs change with time and the location of the strike price to the spot price.
- Nonlinear derivatives come with nonlinear risk exposure where the distribution of returns is skewed. Because the returns of a nonlinear derivative are not normally distributed, a standard VaR model would not work and instead, another model, such as a Monte Carlo VaR, would need to be used.
- Nonlinear derivatives, such as options, depend on a variety of characteristics and it is difficult to collect the historical data on the returns because the option returns would need to be conditioned on all of the characteristics to use the standard VaR approach.
- The VaR calculation of a portfolio containing nonlinear exposures is usually calculated using Monte Carlo VaR simulations of options pricing models to estimate the VaR of the portfolio.

10. What is the Expected Shortfall? How is it estimated?

Expected shortfall is the conditional expectation of loss given that the loss is beyond the VaR level.

Expected shortfall is calculated by averaging all of the returns in the distribution that are worse than the VAR of the portfolio at a given level of confidence. For instance, for a 95% confidence level, the expected shortfall is calculated by taking the average of returns in the worst 5% of cases.

11. Why is Expected Shortfall considered better than VaR?

VaR is also sometimes referred to as conditional VAR, or tail loss. Where VAR asks the question 'how bad can things get?', expected shortfall asks 'if things do get bad, what is our expected loss?'.

One shortcoming of value at risk (VaR) is that it does not tell us anything about losses beyond the VaR level. Expected shortfall is what we expect the loss to be, on average, when a fund exceeds its VaR level.

12. What are the advantages and disadvantages of Expected Shortfall than VaR?

The following are the advantage and dis-advantage of using Expected Shortfall.

Advantages:

ES has better theoretical properties than VAR. If two portfolios are combined, the total ES usually decreases - reflecting the benefits of diversification – and certainly never increases. By contrast, the total VAR can – and in practice occasionally does – increase. This is a more pragmatic reason for preferring ES to VAR in risk management.

Disadvantages:

Back-testing a one-day ES model is much more challenging, because we are interested in the average size of the losses when exceptions are observed. A back-testing period of 250 days is usually used by regulators. This can be expected to give about 6 exceptions when a 97.5% confidence limit is used, which is a small sample.

A key point is that back-testing a stressed model, whether VAR or ES, is not possible because we are interested in whether the model performs well for another stressed period, but we do not have another such period to use for testing.

13. How would you describe Markov chains?

A Markov chain is a stochastic process that satisfies the Markov property, which means that the past and future are independent when the present is known. This means that if one knows the current state of the process, then no additional information of its past states is required to make the best possible prediction of its future. This simplicity allows for great reduction of the number of parameters when studying such a process.

A Markov chain outlines the probability associated with a sequence of events occurring based on the state in the previous event. When approaching Markov chains there are two different types; discrete-time Markov chains and continuous-time Markov chains. This means that we have one case where the changes happen at specific states and one where the changes are continuous.

One example to explain the discrete-time Markov chain is the price of an asset where the value is registered only at the end of the day. One well known example of continuous-time Markov chain is the Poisson process, which is often practiced in queueing theory.

Options and Derivatives

14. What is Ito's Lemma?

Ito's Lemma is a key component in the Ito Calculus, used to determine the derivative of a time-dependent function of a stochastic process. It performs the role of the chain rule in a stochastic setting, analogous to the chain rule in ordinary differential calculus. Ito's Lemma is a cornerstone of quantitative finance and it is intrinsic to the derivation of the Black-Scholes equation for contingent claims (options) pricing.

It can be heuristically derived by forming the Taylor series expansion of the function up to its second derivatives and retaining terms up to first order in the time increment and second order in the Wiener process increment.

Equation for Ito's Lemma

Suppose that the value of a variable x follows the Itô process

$$dx = a(x, t)\,dt + b(x, t)\,dz \tag{14.11}$$

where dz is a Wiener process and a and b are functions of x and t. The variable x has a drift rate of a and a variance rate of b^2. Itô's lemma shows that a function G of x and t follows the process

$$dG = \left(\frac{\partial G}{\partial x}a + \frac{\partial G}{\partial t} + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}b^2\right)dt + \frac{\partial G}{\partial x}b\,dz \tag{14.12}$$

where the dz is the same Wiener process as in equation (14.11). Thus, G also follows an Itô process, with a drift rate of

$$\frac{\partial G}{\partial x}a + \frac{\partial G}{\partial t} + \frac{1}{2}\frac{\partial^2 G}{\partial x^2}b^2$$

and a variance rate of

$$\left(\frac{\partial G}{\partial x}\right)^2 b^2$$

15. Define the Black-Scholes model?

The Black-Scholes model, aka the Black-Scholes-Merton (BSM) model, is a differential equation widely used to price options contracts. The option contracts can either be a call option or a put option. The Black-Scholes model requires 5 input variables: the strike price of an option, the current stock price, the time to expiration, the risk-free rate, and the volatility.

To calculate the price of a call option or a put option, the below formula can be used.

$$c = S_0\, N(d_1) - K\, e^{-rT}\, N(d_2)$$

$$p = K\, e^{-rT}\, N(-d_2) - S_0\, N(-d_1)$$

Where

$$d_1 = (\ln(S_0/K) + (r + \sigma^2/2)T) \,/\, \sigma\sqrt{T}$$

$$d_2 = (\ln(S_0/K) + (r - \sigma^2/2)T) \,/\, \sigma\sqrt{T}$$

16. Can you explain the assumptions behind Black Scholes?

The Black-Scholes model makes certain assumptions:

- No dividends are paid out during the life of the option.
- Markets are random (i.e., market movements cannot be predicted).
- There are no transaction costs in buying the option.
- The risk-free rate and volatility of the underlying asset are known and constant.
- The returns on the underlying asset are log-normally distributed.
- The option is European and can only be exercised at expiration.

17. What is your understanding of Implied Volatility?

Implied volatility is the market's forecast of a likely movement in a security's price. It is a metric used by investors to estimate future fluctuations (volatility) of a security's price based on certain predictive factors.

IV doesn't predict the direction in which the price change will proceed. For example, high volatility means a large price swing, but the price could swing upward (very high), downward (very low), or fluctuate between the two directions. Low volatility means that the price likely won't make broad, unpredictable changes.

18. What are the pros and cons of Implied Volatility?

Pros

1. Implied volatility helps to quantify market sentiment. It estimates the size of the movement an asset may take. However, as mentioned earlier, it does not indicate the direction of the movement.
2. Option writers will use calculations, including implied volatility, to price options contracts.
3. Also, many investors will look at the IV when they choose an investment. During periods of high volatility, they may choose to invest in safer sectors or products.

Cons

1. Implied volatility does not have a basis on the fundamentals underlying the market assets, but is based solely on price.

2. Also, adverse news or events such as wars or natural disasters may impact the implied volatility.
3. IV doesn't predict the direction in which the price change will proceed. For example, high volatility means a large price swing, but the price could swing upward (very high), downward (very low), or fluctuate between the two directions.

Pros	Cons
Quantifies market sentiments, uncertainty.	Based solely on prices, not fundamentals.
Helps set options price.	Sensitive to unexpected factors, news events.
Determines trading strategy.	Predicts movements, but not direction.

19. How is Implied Volatility different from Historical Volatility? How do you compute Implied Volatility and Historical Volatility?

Implied volatility is a measure that seeks to quantify the expected movement of a security's price. It differs materially from historical volatility, which is calculated from the known past returns of a security. Implied volatility is a forward-looking measure of future volatility as opposed to a backward-looking measure of realized volatility.

Estimate Implied Volatility and Historical Volatility:

Implied volatility is observed in the market as the volatility implied in options' prices. The only way to compute the IV is to use an options pricing model, such as the Black-Scholes Model, to solve for the volatility given the market price.

Historical volatility of an asset can be computed by looking at the variance of its returns over a certain period of time. It is computed by multiplying the standard deviation (which is the square root of the variance) by the square root of the number of time periods in question, T.

$$\left(\sigma_T = \sigma\sqrt{T}\right)$$

20. List the factors that affect Implied Volatility?

1. **Supply and demand** are major determining factors for implied volatility. When an asset is in high demand, the price tends to rise. So does the implied volatility, which leads to a higher option premium due to the risky nature of the option. The opposite is also true. When there is plenty of supply but not enough market demand, the implied volatility falls, and the option price becomes cheaper.

2. Another premium influencing factor is the **time value of the option**, or the amount of time until the option expires. A short-dated option often results in low implied volatility, whereas a long-dated option tends to result in high implied volatility.

21. What is a Volatility Smile and Volatility Skew?

A situation in which at-the-money options have lower implied volatility than out-of-the-money or in-the-money options is sometimes referred to as a **volatility "smile"** due to the shape the data creates when plotting implied volatilities against strike prices on a chart. In other words, a volatility smile occurs when the implied volatility for both puts and calls increases as the strike price moves away from the current stock price. In the equity markets, a volatility skew occurs because money managers usually prefer to write calls over puts.

The volatility skew is represented graphically to demonstrate the IV of a particular set of options. Generally, the options used share the same expiration date and strike price, though at times only share the same strike price and not the same date. The graph is referred to as a volatility “smile” when the curve is more balanced or a volatility “smirk” if the curve is weighted to one side.

The main difference between a Volatility Smile and a Volatility Skew/Smirk is that while near-term equity options and forex options lean more toward aligning with a volatility smile, index options and long-term equity options tend to align more with a volatility skew. The skew/smirk shows that implied volatility may be higher for ITM or OTM options.

22. Define Put Call Parity?

Put-call parity shows the relationship that has to exist between European put and call options that have the same underlying asset, expiration, and strike prices. The put-call parity is based on the **no-arbitrage principle**: If there are 2 assets or portfolios whose payoffs are the same under all future scenarios, they should have the same price.

If they don't follow no-arbitrage principle than an arbitrage opportunity exists: You can make sure profit by buying the underpriced asset and simultaneously selling the overpriced asset.

You can determine the put-call party by using the formula $C + PV(K) = P + S$.

.. where:

C = Call option price

P = Put option price

S = Underlying price

$PV(K) = Ke^{-rT}$ = Present value of strike price (same strike for call and put).

23. Can you explain the portfolios used in the Put Call Parity? And how does the portfolio look at expiration?

The two assets (or portfolios) in the put-call parity formula are:

a) P + S = Put option and its underlying security.
b) C + PV(K) = Call option and a (riskless government) bond or money market instrument.

When you hold a stock and a put option on it, it is effectively the same as holding a call option (with the same strike, expiration, and underlying) and bond with maturity same as the options and face value equal to the options' strike price.

Three Scenarios at Expiration

At expiration, underlying price ST can be above, below, or equal to the options' strike K.

a) If ST > K:

The put option expires worthless and the first portfolio is just the underlying. Its value is ST.

The call option is in the money. You exercise it, which means you buy the underlying for the strike price K, which is exactly the cash you get from the maturing bond. You have the underlying, now worth ST. The two portfolios are identical.

b) If ST < K:

The put option is in the money. You exercise it, which means you sell the underlying (which you have) for the strike price K. You are left with no securities, just cash amount K.

The call expires worthless. The bond matures and you get its face value K. Same cash amount as the first portfolio.

c) If ST = K:

The put expires worthless and the first portfolio is just the underlying – its value is ST. You can sell it in the market and get K in cash.

The call expires worthless. The bond matures and you get its face value K. Same cash amount as the first portfolio.

Under all three scenarios, both portfolios end up with the same value when the options expire: The higher of ST and K.

24. List the assumptions of the Put Call Parity?

The put-call parity principle works on the following assumptions.

- The interest rate does not change with time, and it is constant.
- The dividends to be received from the underlying stock are known and certain.
- The underlying stock is liquid, and there are no transfer barriers.

25. Define Binomial Tree?

A binomial tree is a representation of the intrinsic values an option may take at different time periods. The value of the option at any node depends on the probability that the price of the underlying asset will either decrease or increase at any given node.

A binomial tree is a useful tool when pricing **American options** and **embedded options**. Its simplicity is its advantage and disadvantage at the same time. The tree is easy to model out mechanically, but the problem lies in the possible values the underlying asset can take in one period.

26. Are there any assumptions made in the Binomial Option Pricing Model?

There are a few major assumptions in a binomial option pricing model. First, there are only two possible prices, one up and one down. Second, the underlying asset pays no dividends. Third, the interest rate is constant, and fourth, there are no taxes and transaction costs.

27. Explain the difference between arbitrage, hedging, and speculation?

Arbitrage

Arbitrage is the act of buying and selling an asset simultaneously in different markets to profit from a mismatch in prices. Arbitrage opportunities arise due to the inefficiency of the markets. Arbitrage is a common practice in currency trade and stocks listed on multiple exchanges.

Arbitrage opportunities are very short-lived as markets have been designed to be highly efficient. Once an arbitrage opportunity is used, it quickly disappears as the mismatch is corrected.

Hedging

A hedge is an investment that is made with the intention of reducing the risk of adverse price movements in an asset. Normally, a hedge consists of taking an offsetting or opposite position in a related security. There is a risk-reward tradeoff inherent in hedging; while it reduces potential risk, it also chips away at potential gains.

There are various kinds of options and futures contracts that allow investors to hedge against almost any investment, including those involving stocks, interest rates, currencies, commodities, and more.

Speculation

Speculators trade based on their educated guesses on where they believe the market is headed. For example, if a speculator thinks that a stock is overpriced, they may sell short the stock and wait for the price to decline, at which point it can be bought back for a profit.

Speculators are vulnerable to both the downside and upside of the market; therefore, speculation can be extremely risky. But when they win, they can win big—unlike hedgers, who aim more for protection than for profit.

If hedgers can be characterized as risk-averse, speculators can be seen as risk-lovers. Hedgers try to reduce the risks associated with uncertainty, while speculators bet against the movements of the market to try to profit from fluctuations in the price of securities. Both may swim against the tide of market sentiment, but they do so out of very different motives.

28. What are the Greeks?

"Greeks" is a term used in the options market to describe the different dimensions of risk involved in taking an options position. Traders use different Greek values, such as delta, theta, and others, to assess options risk and manage option portfolios.

29. Define Greeks with respect to Options?

The primary Greeks with respect to Options are Delta, Gamma, Theta, Vega, and Rho.

Delta (Δ) represents the rate of change between the option's price and a $1 change in the underlying asset's price. In other words, the price sensitivity of the option is relative to the underlying asset. Delta of a call option has a range between 0 and 1, while the delta of a put option has a range between 0 and -1. For example, assume an investor is long a call option with a delta of 0.50. Therefore, if the underlying stock increases by $1, the option's price would theoretically increase by 50 cents.

For options traders, delta also represents the hedge ratio for creating a delta-neutral position. For example, if you purchase a standard American call option with a 0.40 delta, you will need to sell 40 shares of stock to be fully hedged. Net delta for a portfolio of options can also be used to obtain the portfolio's hedge ratio.

Gamma (Γ) represents the of change rate between an option's delta and the underlying asset's price. This is called second-order (second-derivative) price sensitivity. Gamma indicates the amount the delta would change given a $1 move in the underlying security. For example, assume an investor is long on a call option on hypothetical stock XYZ. The call option has a delta of 0.50 and a gamma of 0.10. Therefore, if stock XYZ increases or decreases by $1, the call option's delta would increase or decrease by 0.10.

Theta (Θ) represents the rate of change between the option price and time, or time sensitivity - sometimes known as an option's time decay. *Theta indicates the amount an option's price would decrease as the time to expiration decreases, all else equal.* For example, assume an investor is long an option with a theta of -0.50. The option's price would decrease by 50 cents every day that passes, all else being equal.

Vega (v) represents the rate of change between an option's value and the ***underlying asset's implied volatility***. This is the option's sensitivity to volatility. Vega indicates the amount an option's price changes given a 1% change in implied volatility. For example, an option with a Vega of 0.10 indicates the option's value is expected to change by 10 cents if the implied volatility changes by 1%.

Rho (p) represents the rate of change between an option's value and a 1% change in the interest rate. This measures sensitivity to the interest rate. For example, assume a call option has a rho of

0.05 and a price of $1.25. If interest rates rise by 1%, the value of the call option would increase to $1.30, all else being equal. The opposite is true for put options. *Rho is greatest for at-the-money options with long times until expiration*.

Rho is positive for long options (long calls and short puts) but negative for short options (short calls and long puts). In other words, an increase in interest rate is generally good news for long options, whereas short options tend to benefit if interest rate decreases.

30. What is delta and gamma hedging?

Delta Hedging: Delta hedging is an options strategy that seeks to be directionally neutral by establishing offsetting long and short positions in the same underlying.

Delta hedging can benefit traders when they anticipate a strong move in the underlying stock but run the risk of being over hedged if the stock doesn't move as expected. If over hedged positions have to unwind, the trading costs increase.

One of the primary drawbacks of delta hedging is the necessity of constantly watching and adjusting the positions involved. Depending on the movement of the stock, the trader has to frequently buy and sell securities to avoid being under or over hedged. It can also incur trading costs as delta hedges are added and removed as the underlying price changes.

Gamma Hedging: Gamma hedging is a trading strategy that tries to maintain a constant delta in an options position, often one that is delta-neutral, as the underlying asset changes price. It is used to reduce the risk created when the underlying security makes strong up or down moves, particularly during the last days before expiration. A gamma-neutral portfolio is thus hedged against second-order time price sensitivity.

Gamma hedging is employed at an option's expiration to immunize the effect of *rapid changes in the underlying asset's price* that can occur as the time to expiry nears whereas a delta hedge strategy, in comparison, only reduces the effect of *relatively small underlying price changes* on the options price.

31. Are you aware of the stochastic volatility models?

Stochastic volatility (SV) refers to the fact that the volatility of asset prices varies and is not constant, as is assumed in the Black Scholes options pricing model. Stochastic volatility modeling attempts to correct for this problem with Black Scholes by allowing volatility to fluctuate over time.

Models based on Black-Scholes assume that the underlying volatility is constant over the life of the derivative, and unaffected by the changes in the price level of the underlying security. However, by assuming that the volatility of the underlying price is a stochastic process rather than a constant, it becomes possible to model derivatives more accurately.

Models that are used for stochastic volatility modeling are:

- Heston Model
- CEV Model (Constant elasticity of variance model)

- SABR Volatility Model (Stochastic Alpha, Beta, Rho)
- GARCH Model (Generalized Autoregressive Conditional Heteroskedasticity)
- 3/2 Model

32. Do you know any one-factor or multi-factor short-rate models?

One-factor short rate models work under the assumption that the future evolution of the interest rates is dependent on only one stochastic factor whereas multiple-factor short rate models work under the assumption that more than one stochastic factor affect the future evolution of the interest rates.

Following are the one-factor models, where a single stochastic factor – the short rate – determines the future evolution of all interest rates.

- Merton's model
- Vasicek model
- Rendleman–Bartter model
- Cox–Ingersoll–Ross model
- Ho–Lee model
- Hull–White model

Besides the above one-factor models, there are also multi-factor models of the short rate, among them the best known are the **Longstaff and Schwartz** two factor model and the **Chen three factor model**.

Note that for the purposes of risk management, "to create realistic interest rate simulations", these multi-factor short-rate models are sometimes preferred over One-factor models, as they produce scenarios which are, in general, better "consistent with actual yield curve movements".

33. What is the Vasicek Interest Rate Model? How does the Vasicek Interest Rate Model works?

The term Vasicek Interest Rate Model refers to a mathematical method of modeling the movement and evolution of interest rates. It is a single-factor short-rate model that is based on market risk. The Vasicek interest rate model values the instantaneous interest rate using the following equation:

$$(dr_t = a(b - r_t)dt + \sigma dW_t)$$

Where:

W = Random market risk (represented by a Wiener process)
T = Time period
a ($b - r_t$) = Expected change in the interest rate at time t (the drift factor)
a = Speed of the reversion to the mean
b = Long-term level of the mean
σ = Volatility at time t

The Vasicek model exhibits a mean-reversion, which helps predict future interest rate movements. The Vasicek model states that the interest rate fluctuates around the long-term mean level. Therefore, an increase in the interest rate followed by a mean reversal to its long-term level b forms a resistance level.

Short Rate (r_t)	**Rate Change (dr_t)**
$r_t > b$ Short Rate is greater than Long Term Rate	$dr_t = a(b-r_t) < 0$ Adjust Short Rate Process Downwards
$r_t < b$ Short Rate is less than Long Term Rate	$dr_t = a(b-r_t) > 0$ Adjust Short Rate Process Upwards

Table: Mean Reverting Drift: $dr_t = a(b-r_t)$

Similarly, a decrease in the interest rate followed by a "bounce" back to its long-term mean level b forms a support level.

34. What are the limitations of the Vasicek Interest Rate Model?

Although the Vasicek model was an important step forward in developing predictive interest rate models, it exhibits two key limitations:

1) It is a single-factor model

The volatility of the market (or market risk) is the only factor that affects interest rate changes in the Vasicek model. However, multiple factors may affect the interest rate in the real world, which makes the model less practical.

2) It allows interest rates to be negative

The Vasicek model allows for negative interest rates, which is a highly undesirable scenario for any economy. Negative interest rates are employed by central banks in times of extreme financial crises and are considered highly improbable. However, in recent times, it's become evident that negative interest rates are used as a monetary policy tool by central banks.

35. What is the Cox-Ingersoll-Ross Model (CIR) Interest Rate Model?

The CIR is a one-factor equilibrium model that uses a square-root diffusion process to ensure that the calculated interest rates are always non-negative.

The equation for the CIR model is expressed as follows:

$$\left(dr_t = a(b - r_t)dt + \sigma\sqrt{r_t}dW_t\right)$$

Where:

rt = Instantaneous interest rate at time t

a = Rate of mean reversion

b = Mean of the interest rate

Wt = Wiener process (random variable modeling the market risk factor)

σ = Standard deviation of the interest rate (measure of volatility)

The Cox-Ingersoll-Ross (CIR) model was derived from the Vasicek Interest Rate model, which was also a mathematical formula used in the evaluation of interest rate movements. However, the Vasicek model does not include a square root component and it sometimes model negative interest rates. CIR has an advantage over the Vasicek model because it does not allow for or model negative interest rates.

36. What are the limitations of the Cox-Ingersoll-Ross Model (CIR) Interest Rate Model?

Following are the limitations of the Cox-Ingersoll-Ross Model (CIR) model.

1) The CIR Model cannot be used in negative interest rate environment since the model only generates positive values.

2) For a short rate one factor model like CIR the assumption is that there is only one source of randomness in the yield curve, which is the short-term interest rate. This implies that longer term rates are perfectly correlated to the short-term rate. Using this assumption is it then possible to model the longer-term rates. Some methods of how this may be done is by assuming that the longer-term rates change by the same proportion as the short-term rates, another method is to assume that the current spreads between the short rate and longer-term rate are representative of future spreads, etc.

   This assumption of perfect correlation is one of the disadvantages of using the one-factor CIR Model as empirically this is not the case. Besides the level of the yield curve (as given by the uncertainty in the short rate) the yield curve may be impacted by other significant factors such as slope (or tilt as given by the difference between yields of different maturities), twist, etc.

37. What's the difference between forward and future?

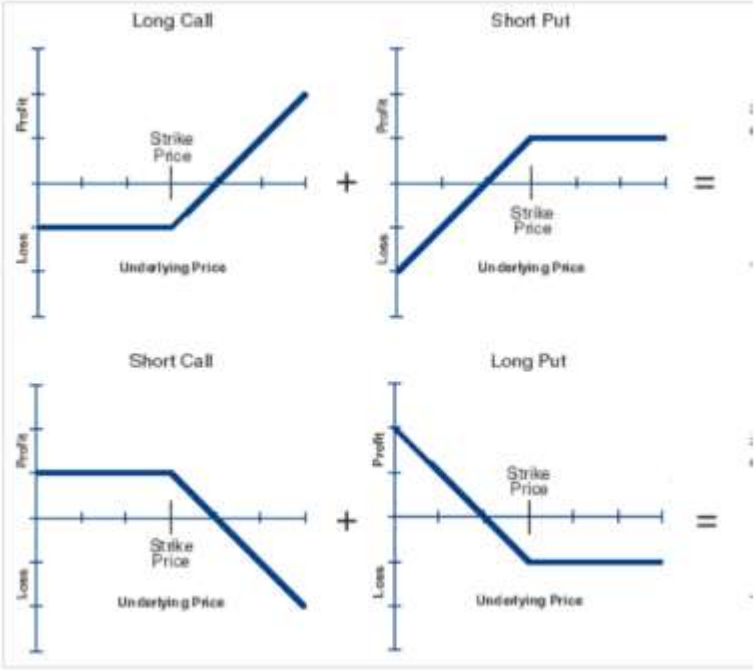
Sr. No.	Forward	Future
1	A forward contract is a private and customizable agreement that settles at the end of the agreement and is traded over the counter.	A futures contract has standardized terms and is traded on an exchange, where prices are settled on a daily basis until the end of the contract.
2	There is no oversight with respect to forward contracts.	Futures are regulated by the Commodity Futures Trading Commission.
3	There is more counterparty risk associated with forwards.	Futures are less risky as there is almost no chance for default since they are mark to market daily.

Sr. No.	Forward	Future
4	In the case of a forward contract, there are high chances of default by a party, as the agreement is private in nature.	In future contract, clearing houses are involved that guarantees the transaction, so the possibility of default is almost nil.
5	Forward contracts are settled at maturity.	Futures are settled daily (not just at maturity).
6	In forward contracts, there is no requirement of collateral.	In futures contracts, initial margin is required.
7	Forward contracts can be used for both hedging and speculation, but as the contract is tailor made, it is best for hedging.	Futures contracts are appropriate for speculation.

38. What's the difference between call option and put option?

Sr. No.	Call Option	Put Option
1	Buyer of a call option has the right, but is not required, to buy an agreed quantity by a certain date for a certain price (the strike price).	Buyer of a put option has the right, but is not required, to sell an agreed quantity by a certain date for the strike price.
2	Seller (writer of the call option) obligated to sell the underlying asset to the option holder if the option is exercised.	Seller (writer of a put option) obligated to buy the underlying asset from the option holder if the option is exercised.
3	A call option is bought if the trader expects the price of the underlying asset to rise within a certain time frame.	A put option is bought if the trader expects the price of the underlying asset to fall within a certain time frame.
4	The value of call option increases as value of the underlying asset increases	The value of put option decreases as value of the underlying asset increases.

39. Draw the graphs of short call, short put, long call and long put?



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***Fixed Income ***

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40. What are Bonds? What are the characteristics of Bonds?

A bond is a fixed-income instrument that represents a loan made by an investor to a borrower (typically corporate or governmental). It is referred to as a fixed-income instrument since bonds traditionally paid a fixed interest rate (coupon) to debtholders. Bonds are used by companies, municipalities, states, and sovereign governments to finance projects and operations.

Most bonds share some common basic characteristics including:

- **Face value** (par value) is the money amount the bond will be worth at maturity.
- **The coupon rate** is the rate of interest the bond issuer will pay on the face value of the bond, expressed as a percentage.
- **Coupon dates** are the dates on which the bond issuer will make interest payments. Payments can be made in any interval, but the standard is semiannual payments.
- **The maturity date** is the date on which the bond will mature and the bond issuer will pay the bondholder the face value of the bond.
- **The issue price** is the price at which the bond issuer originally sells the bonds. In many cases, bonds are issued at par.

41. What's the difference between stocks and bonds?

Parameter	Stock	Bond
Definition	Stocks represent partial ownership, or equity, in a company. When you buy stock, you're actually purchasing a tiny slice of the company — one or more "shares."	Bonds are a loan from you to a company or government. There's no equity involved, nor any shares to buy. Put simply, a company or government is in debt to you when you buy a bond, and it will pay you interest on the loan for a set period, after which it will pay back the full amount you bought the bond for.
Capital Gains	Stocks and bonds generate cash in different ways, too. To make money from stocks, you'll need to sell the company's shares at a higher price than you paid for them to generate a profit or capital gain.	Bonds generate cash through regular interest payments. The distribution frequency can vary, but it's generally as follows: ○ Treasury bonds and notes: Every six months until maturity. ○ Treasury bills: Only upon maturity. ○ Corporate bonds: Semiannually, quarterly, monthly or at maturity.
Inverse performance	Historically, when stock prices are rising and more people are buying to capitalize on that growth, bond prices have typically fallen on lower demand.	Conversely, when stock prices are falling and investors want to turn to traditionally lower-risk, lower-return investments like bonds, their demand increases, and in turn, their prices.
Risks and Rewards	The biggest risk of stock investments is the share value decreasing after you've purchased them. There are several reasons stock prices fluctuate, but in short, if a company's performance doesn't live up to investor expectations, its stock price could fall.	U.S. Treasury bonds are generally more stable than stocks in the short term, but this lower risk typically translates to lower returns. Corporate bonds, on the other hand, have widely varying levels of risk and returns.

42. What's the meaning of duration? State the limitations of duration as a risk measure?

Duration measures a bond's or fixed income portfolio's price sensitivity to interest rate changes. A bond's duration is easily confused with its term or time to maturity because certain types of duration measurements are also calculated in years.

Macaulay duration estimates how many years it will take for an investor to be repaid the bond's price by its total cash flows while Modified duration measures the price change in a bond given a 1% change in interest rates.

The main limitation of duration is that it assumes a linear relationship between interest rates and bond price. In reality, the relationship is likely to be curvilinear. The extent of the deviation from a linear relationship is known as convexity.

43. What are the common types of bonds that are traded in the financial market?

The U.S. Bond market is the largest bond market in the world. The common types of bonds are:

a) U.S. Treasuries (treasury bills, notes, bonds, and inflation indexed).
b) Agency bonds (federally related institutions & government-sponsored enterprises).
c) Municipals bonds (state & local governments).
d) Corporates bonds.
e) Asset backed securities.
f) Mortgage-backed securities.

44. What all factors affect duration of a bond?

Certain factors can affect a bond's duration, including:

- **Time to maturity:** The longer the maturity, the higher the duration, and the greater the interest rate risk. Consider two bonds that each yield 5% and cost $1,000, but have different maturities. A bond that matures faster—say, in one year—would repay its true cost faster than a bond that matures in 10 years. Consequently, the shorter-maturity bond would have a lower duration and less interest rate risk.

- **Coupon rate:** A bond's coupon rate is a key factor in calculation duration. If we have two bonds that are identical with the exception of their coupon rates, the bond with the higher coupon rate will pay back its original costs faster than the bond with a lower yield. The higher the coupon rate, the lower the duration, and the lower the interest rate risk.

45. What is convexity? Why is it important?

Convexity is a measure of the curvature, or the degree of the curve, in the relationship between bond prices and bond yields. Convexity demonstrates how the duration of a bond changes as the interest rate changes. If a bond's duration increases as yields increase, the bond is said to have negative convexity. If a bond's duration rises and yields fall, the bond is said to have positive convexity.

Portfolio managers will use convexity as a risk-management tool, to measure and manage the portfolio's exposure to interest rate risk. Bond A has a higher convexity than Bond B, which indicates that all else being equal, Bond A will always have a higher price than Bond B as interest rates rise or fall.

46. Explain different types of risks in Treasury Bond?

Bonds can be a great tool to generate income and are widely considered to be a safe investment, especially compared with stocks. However, investors should be aware of the potential pitfalls of holding corporate bonds and government bonds. Below, we'll discuss the risks that could impact your hard-earned returns.

a) **Interest rate risk:** The first thing a bond buyer should understand is the inverse relationship between interest rates and bond prices. As interest rates fall, bond prices rise. Conversely, when interest rates rise, bond prices tend to fall.

b) **Reinvestment risk:** Another danger bond investors face is reinvestment risk, which is the risk of having to reinvest proceeds at a lower rate than what the funds were previously earning. One of the main ways this risk presents itself is when interest rates fall over time and callable bonds are exercised by the issuers.

c) **Inflation risk:** When an investor buys a bond, they essentially commit to receiving a rate of return, either fixed or variable, for the time that the bond is held. And what happens if the cost of living and inflation increase dramatically, and at a faster rate than income investment? When this happens, investors will see their purchasing power erode, and they may actually achieve a negative rate of return when factoring in inflation.

d) **Credit (Default) risk:** Credit risk is the risk of a loss due to the bond issuer not making the required principal or interest payments on time or at all. When an issuer misses a payment, it is considered to be in default.

e) **Downgrade risk:** If an issuer's credit rating is low or its ability to operate and repay is questioned, banks and lending institutions will take notice and may charge a higher interest rate for future loans. This can adversely impact the company's ability to satisfy its debts and hurt existing bondholders who might have been looking to unload their positions.

f) **Liquidity risk:** There is a risk an investor might not be able to sell their corporate bonds quickly due to a thin market with few buyers and sellers for the bond. Low buying interest in a particular bond issue can lead to substantial price volatility and adversely impact a bondholder's total return upon sale.5 Much like stocks that trade in a thin market, you may be forced to take a far lower price than expected when selling your position in the bond.

47. Define yield spread and what all factors affect yield spread?

The difference between the yield on any two bonds with different maturities is called the yield spread. The spread is straightforward to calculate since you subtract the yield of one from that of the other in terms of percentage or basis points.

The yield spread between the two- & ten-years treasuries which displays how much additional yield an investor can get by taking on the added risk of investing in long-term bonds.

Factors affecting the spread are:

a) the type of issuer (e.g., agency, corporate, municipality),
b) creditworthiness of issuer,
c) the maturity of the instrument,
d) the embedded options (e.g., call, put, or conversion provisions),
e) the taxability of interest income at the federal and municipal levels,
f) the expected liquidity of the issue, and
g) the finance ability of an issue

48. Which one is more convex? A 5-year zero coupon bond vs 5-year 3% coupon paying bond.

A 5-year zero coupon bond is more convex since a 5-year 3% bond will pay coupon semiannually and is less exposed to interest rate risk while in zero coupon bond you will get all the cash flow at the maturity. Therefore, the interest rate risk will be high on 5-year zero coupon bond and hence its more convex.

49. Which has greater interest rate risk? A 30-year treasury bond or a 30 year BB corporate bond?

A 30-year Treasury bond has a greater interest rate risk than the 30-year BB corporate bond. This is because the former has lower coupon rates resulting from its lower default risk. When the coupon rate is low, the bond price responds to changes in the market interest rate. This increases the interest rate risk.

50. Which is more volatile? A 20-year zero coupon bond or a 20-year 4.5% coupon bond?

Zero-coupon bonds tend to be more volatile because they do not pay any interest during the life of the bond. These bondholders receive the face value on maturity, thus the only value in these bonds happens closer to maturity. The closer to maturity the more the bond is worth. There is limited liquidity since they are not impacted by interest rate changes, which makes their value even more volatile.

*** I am super proud that you have made it. I hope that the above questions might have given you some insights into how the interview process looks like****

*** Rest of the questions on Options & Derivatives, Fixed Income, Monte Carlo, Stochastic Calculus, Statistics etc., will be covered in Part II ****

***** Thank You …!! *****