Module 2

Option pricing in detail

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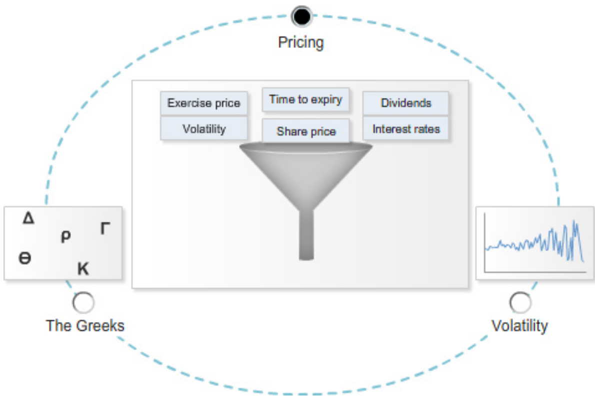
Topic 1: Influences on option prices - recap

Which stock to buy?

This topic provides a brief recap of the basics of option pricing, which were first covered in Module 3 of the 'Introduction to Options' course.



If you are not familiar with this material, you may benefit from revising Module 3 of the introductory course. It is important you are comfortable with the fundamentals of option pricing before proceeding with the more in-depth coverage of pricing in this module.

In Topics 2 - 5 of this module we will consider option pricing in some detail, with a particular focus on volatility and the 'Greeks'.

Intrinsic value and time value

An option's premium can be broken into two parts, intrinsic value and time value.

Current share price: $4.80				
Option type	Exercise price	Premium	Intrinsic value	Time value
Call	4.50	0.45	0.30	0.15
Call	5.00	0.17	0.00	0.17
Put	4.50	0.12	0.00	0.12
Put	5.00	0.33	0.20	0.13

Intrinsic value
Intrinsic value is the difference between the option's exercise price and the current share price.

Call options have intrinsic value if the share price is above the exercise price. Put options have intrinsic value if the share price is below the exercise price.

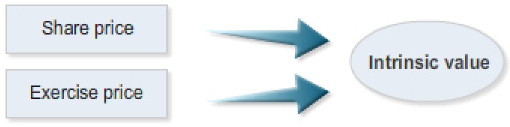
Time value
Before expiry, an option will usually trade for more than its intrinsic value.

The part of the premium over and above its intrinsic value is time value.

Influences on option premiums

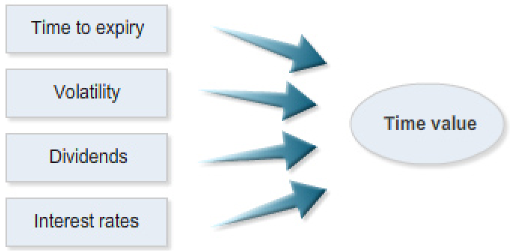
An option's intrinsic value depends on:

- the strike price of the option
- the price of the underlying shares



An option's time value is influenced by:

- time to expiry
- volatility
- dividends
- interest rates



Time to expiry
The longer the time to expiry, the greater an option's time value, all else being equal.

As time passes, an option's time value decreases. This is called 'time decay'.

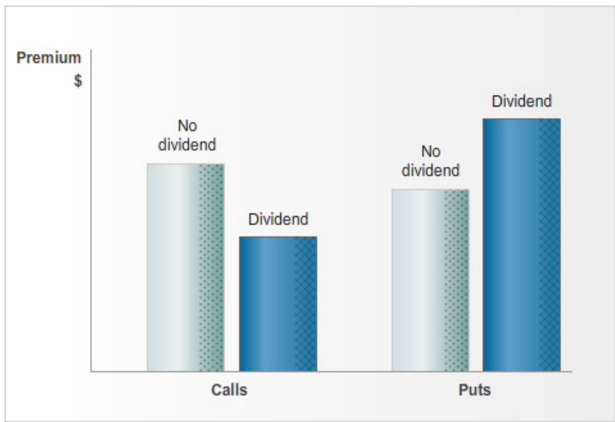
Time decay is not constant. In the early stages of an option's life it is slower, and accelerates as expiry approaches.

Volatility
The more volatile the stock, the higher the option's premium, all else being equal.

Volatility refers to the size and speed of movements in the share price - in other words, how far and how fast the price moves.

Dividends
If the stock goes ex-dividend during the option's life, call premiums will be lower, and put premiums higher, than if the stock does not go ex-dividend during this period.

This is because the price of the stock itself usually changes on the ex-dividend date, typically falling by the amount of the dividend, all else remaining constant.

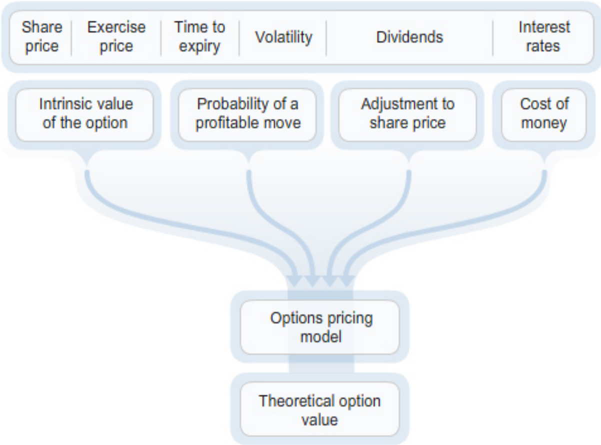


Interest rates
Increases in interest rates lead to higher call premiums and lower put premiums, all else being equal.

This is because options have an inbuilt funding benefit (call options) or a funding cost (put options). The higher interest rates are, the greater the funding benefit/cost is.

Option pricing models

An option pricing model is a formula that produces a theoretical or 'fair' value for an option, based on values for each of the variables we have just looked at.



The theoretical fair value of an option is not necessarily the same as its current market price!

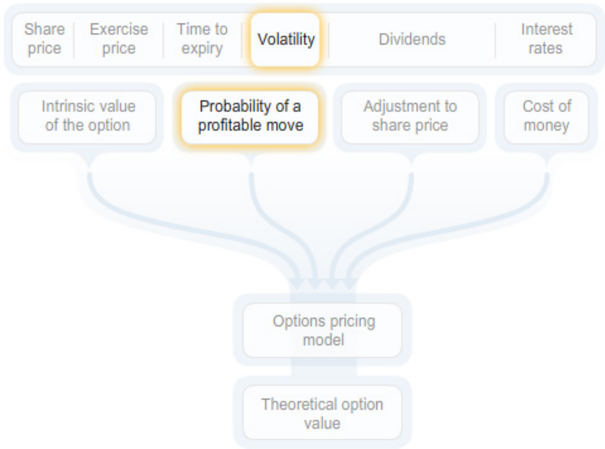
Traders use pricing models to help assess whether options are fairly priced in the market, and to guide them in their trading strategies. There are two main models used to price equity options: the binomial model and the Black Scholes model.

ASX Option Pricing Calculator

The ASX website contains a Theoretical Option Price Calculator.

The calculator automatically inserts default values for the variables that affect an option's price, including ASX estimates of dividends and volatility.

Topic 2: Volatility



A good understanding of volatility is essential for the option trader. After the underlying stock price, volatility is probably the most important influence on an option's price.

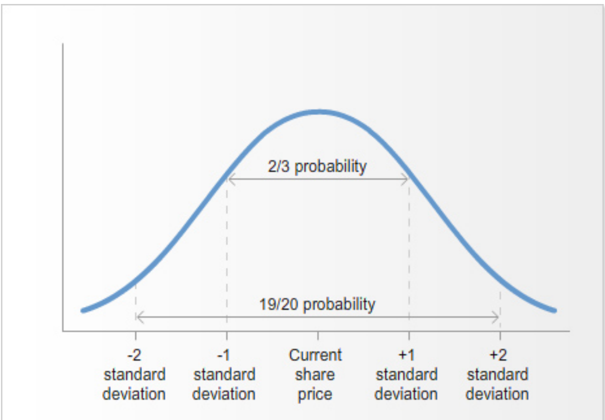
A sound knowledge of volatility will:

- help you to assess whether an option is fairly priced
- guide your choice of strategy
- enable you to anticipate how your strategy will be affected by a change in volatility.

In this topic we explain what volatility means in terms of a stock's likely trading range.

In Topic 3 we explain how and why different options over the same stock may price in different levels of volatility, and look at how changes in volatility can affect your strategy.

Volatility is expressed as a percentage figure (the annualised standard deviation of daily percentage changes in a stock's price).



Much options pricing theory is derived from probability theory, and assumes that share price changes (in percentage terms) are normally distributed.

This means we can use a stock's price and volatility to predict its likely trading range.

Probability theory tells us that after a year there is a probability of roughly:

- 2 in 3 that the share price will be within one standard deviation of the current share price [share price +/- (1 x volatility)].
- 19 in 20 that the share price will be within two standard deviations of the current share price [share price +/- (2 x volatility)].

Probable trading range over 12 months

Let's look at an example.

Assume XYZ shares, currently trading at $10.00, have a volatility of 30%.

Using our rules from the previous screen, after one year there is a probability of roughly:

- 2 in 3 that the shares will be between $7.00 and $13.00 ($10.00 +/- 30%)
- 19 in 20 that the shares will be between $4.00 and $16.00 [$10.00 +/- (2 x 30%)]

	Volatility	2/3 probability trading range	
		Low	High
Stock price = $20.00	20%	$16	$24
	30%	$14	$26
	40%	$12	$28

Calculating trading ranges over shorter periods of time

Most option traders are concerned with periods shorter than a year.

You can use a stock's annualised volatility to calculate its likely trading range over a period of days, weeks, or months.

$$\text{Standard deviation} = \frac{V}{\sqrt{n}} \times P$$

V	Annualised volatility
n	Number of specified time units in a year
$\sqrt{n}$	Square root of n
P	Price of underlying shares

To calculate the standard deviation over a month, the value to use for 'n' is 12, as there are 12 months in a year.

To calculate the standard deviation over a week, 'n' would be 52.

Example: trading range over a month

Let's return to our example of XYZ shares trading at $10.00, with a volatility of 30%.

Using the formula just given, complete the drag and drop activity to calculate the volatility over one month.

$$\text{Standard deviation} = \frac{30\%}{\sqrt{12}} \times \$10.00 = \$0.87$$

This tells us that in a month's time, you can expect XYZ to be between

- $9.13 and $10.87 ($10.00 ± 1 standard deviation of $0.87) about 2/3 of the time
- $8.26 and $11.74 ($10.00 ± 2 standard deviations of $0.87) about 19/20 of the time.

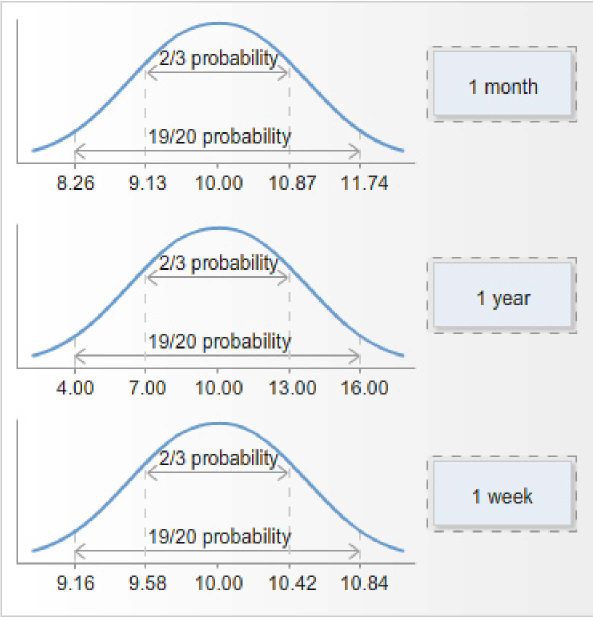
The key assumption behind this calculation is that volatility remains at 30%.

Example: trading range over a week

Volatility over one week can be calculated by changing the square root time period from 12 to 52.

By making this adjustment to the calculation on the previous screen, this tells us that in a week's time, assuming volatility remains at 30%, you can expect XYZ to be between:

- $9.58 and $10.42 ($10.00 ± 1 standard deviation of $0.42) about 2/3 of the time
- $9.16 and $10.84 ($10.00 ± 2 standard deviations of $0.42) about 19/20 of the time.

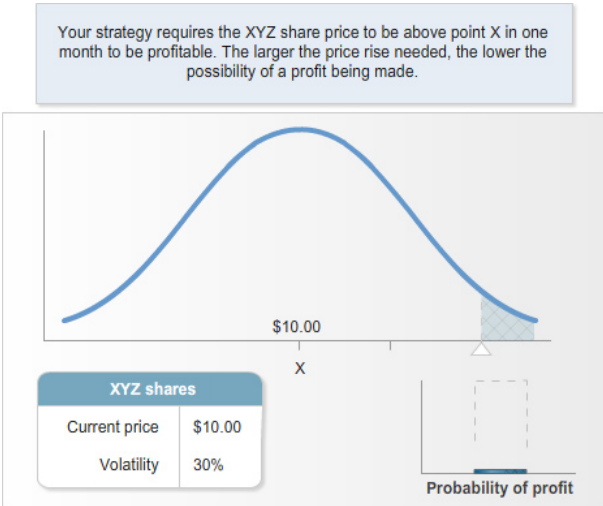


Once you understand what a stock's volatility means in terms of its likely trading range over a given period of time, you are in a better position to assess the chances of an option strategy making a profit.

Taking our XYZ example, assume you think the current volatility of 30% will apply over the next month.

If you are right, there is approximately a 2/3 probability that in a month, XYZ shares will be within $0.87 of the current price of $10.00.

Let's say you are considering a strategy that will make a profit if the stock price moves more than $0.87 in either direction. Probability theory suggests there is around a 1 in 3 chance you will make a profit.



Topic 3: Volatility (continued)

Volatility skew

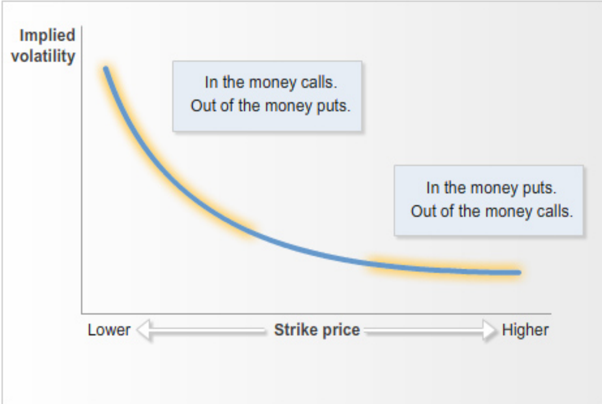
An option's implied volatility is the expected volatility of the underlying stock that is reflected in the current market price of the option.

You might expect all options over the one stock to have the same implied volatility.

However, implied volatility typically varies across different strike prices.

Options with lower exercise prices generally have higher implied volatility than options with higher exercise prices.

This phenomenon is referred to as a 'volatility skew'.



Why does volatility skew exist?

Contrary to what novice traders may believe, volatility skew is not necessarily a sign that options are mispriced.

It comes about primarily because of the activities of traders looking to hedge risk.

Risk to the downside is generally regarded as higher than risk to the upside. Market slumps tend to be more extreme, and to happen faster, than market rises. The cost of hedging downside risk therefore tends to be higher.

The end result is that both puts and calls with lower exercise prices tend to trade at prices reflecting higher implied volatilities than other options in that class.

Implied volatility	Option series
32%	March $8.00 call
30%	March $9.00 put
28%	March $10.00 put
27%	March $11.00 call

What happens if volatility changes?

While stock price is the most important influence on the value of your position, changes in volatility can also significantly affect your strategy.

Even if the share price moves in the expected direction, an unfavourable change in volatility can be damaging.

Implied volatility	52 days to expiry (strategy initiated)	37 days to expiry XYZ $10.00 call price		
	XYZ @ $10	XYZ @ $9.75	XYZ @ $10.00	XYZ @ $10.25
15%		$0.11	$0.22	$0.39
25%	$0.42	$0.23	$0.35	$0.51
35%		$0.36	$0.48	$0.63

If you buy options and volatility falls, you can lose money, even if the share price moves favourably.

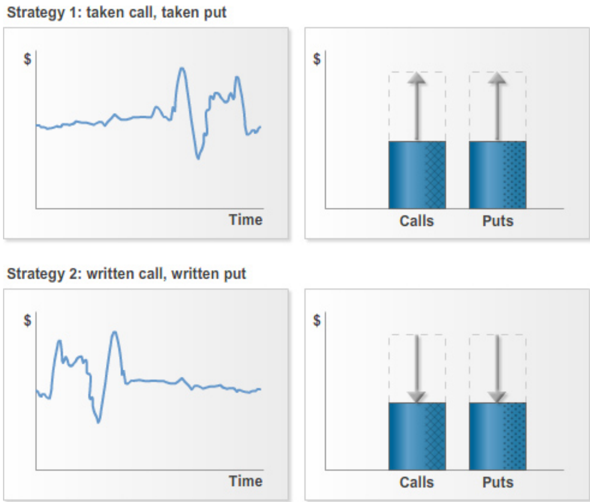
If you write options, an increase in volatility will hurt your strategy.

Example
You buy a $10.00 call option for $0.42, with 52 days to expiry. Implied volatility at the time of purchase is 25%.

Consider your position in various scenarios 15 days later, including:

- stock price rising, falling or remaining steady, and
- volatility rising, falling or remaining steady.

Volatility and multi-legged strategies



If a multi-legged option strategy consists only of bought options, or only of written options, a change in volatility will affect both legs the same way, so the effect on the strategy overall is clear.

For example, with a strategy consisting of a taken call and a taken put, both options will benefit from an increase in volatility and suffer from a decrease.

With a strategy consisting of a written call and a written put, both options will benefit from a decrease in volatility and suffer from an increase.

	Individual legs	Effect of rise in volatility		Overall effect		
Strategy 1	Taken call	✓ Helps	○ Hurts	○ Helps	○ Hurts	✓ Mixed
	Written call	○ Helps	✓ Hurts			
Strategy 2	Taken call	✓ Helps	○ Hurts	✓ Helps	○ Hurts	○ Mixed
	Taken put	✓ Helps	○ Hurts			
Strategy 3	Written put	○ Helps	✓ Hurts	○ Helps	○ Hurts	✓ Mixed
	Taken put	✓ Helps	○ Hurts			
Strategy 4	Written call	○ Helps	✓ Hurts	○ Helps	✓ Hurts	○ Mixed
	Written put	○ Helps	✓ Hurts			

If your position is a combination of taken and written options, the effect of a change in volatility is more complex, as the legs will react differently.

A volatility shift may require action on your part

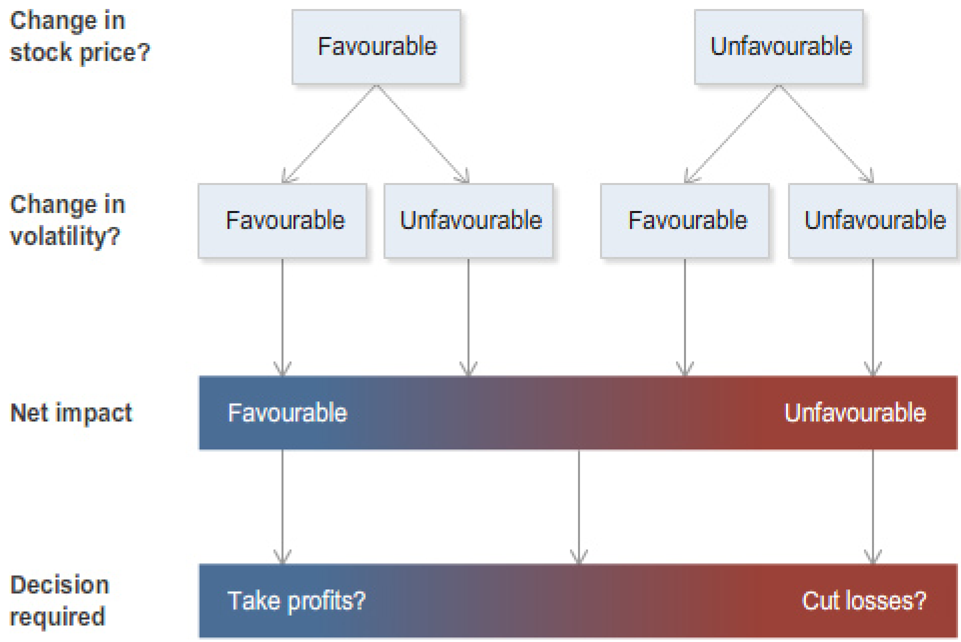
A substantial change in volatility may have a significant effect on your position - either positive or negative.

If the change in volatility is not what you expected, you might want to reassess your position.

If the effect on your position has been favourable, you may want to consider taking profits.

If the effect on your position has been unfavourable, you may want to consider cutting your losses before the strategy is damaged further.

Volatility changes should not be assessed independently from movements in the stock price. Your primary consideration will generally be movements in the stock price, as it is these that have the greatest impact on an option strategy.



Topic 4: The Greeks

What are 'the Greeks'?

As well as producing an option's fair value, an option pricing model provides other useful information about an option's sensitivity to changes in the variables that affect price.

These sensitivity measures are known as 'the Greeks', because they are commonly denoted by Greek letters:

- delta
- gamma
- theta
- vega
- rho

Δ	Delta
Γ	Gamma
Θ	Theta
ν	Vega
ρ	Rho

Traders can use the Greeks to work out how much risk their portfolio is exposed to, and where that risk lies.

You don't need to have an in-depth knowledge of the Greeks in order to trade options. However a familiarity with the basic concepts can help you to better understand the way an option's price behaves.

Delta

Delta is a measure of an option's sensitivity to a change in the price of the underlying shares. It helps you answer the question:

If the share price moves by a certain amount, how might that affect the value of my option?

The formula is:

Share price movement x option delta = likely change in option price

A call option's delta is between zero and 1.
A put option's delta is between zero and -1.

Example
If your option has a delta of 0.6, and the share price rises by $0.10, you would expect the option to rise by $0.06.

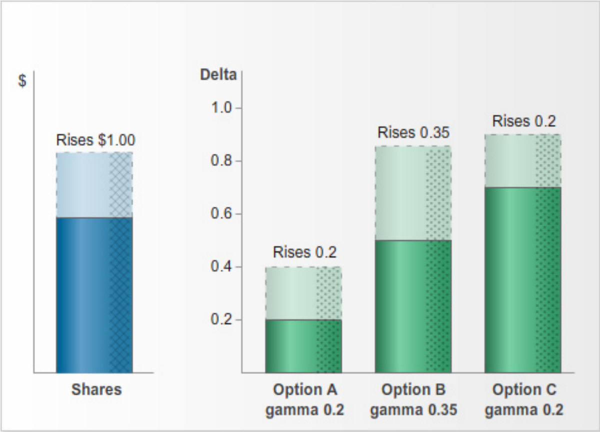
	Share price	Call option
Price	$10.30	$0.57

	Share price	Call option
Price	$9.70	$0.27

The basics of delta are covered in Module 3, 'Option Pricing', of the introductory course.

Delta is perhaps the most useful of the Greeks. We will look at it in more detail in Topic 5.

Gamma



Delta is not constant. As the stock price changes, so does an option's delta.

Gamma is a measure of delta's sensitivity to a change in the stock price. It helps you answer the question:

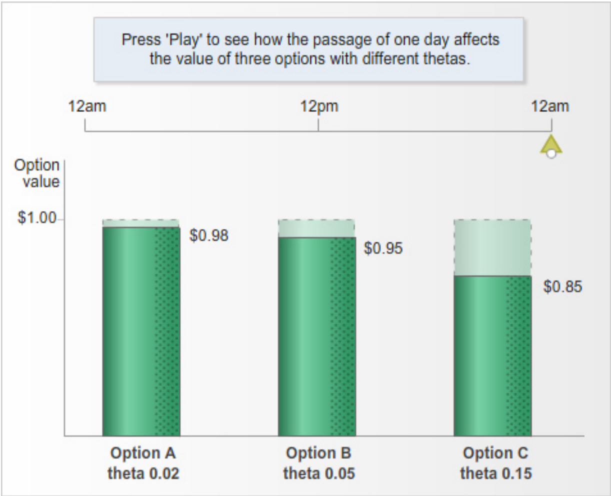
If the share price moves by a certain amount, how might that affect the delta of my option?

Gamma tells you how much the delta should change given a $1.00 movement in the stock price. It is positive for taken option positions, and negative for written positions.

Example
You hold a call option with a delta of 0.50 and a gamma of 0.20. If the stock price rises by $1.00, you would expect your option's delta to increase by around 0.20 to 0.70.

Gamma can be used by traders to monitor and manage the risk of large option positions.

Theta



Theta is a measure of time decay. It helps you answer the question:

Over the next day, how should time decay affect the value of my option?

Theta tells you the amount by which an option's value should fall when time to expiry decreases by one day, all else remaining equal. It is conventionally expressed as a negative number.

At-the-money options have the most time value, therefore they have the highest theta. Theta increases as expiry approaches.

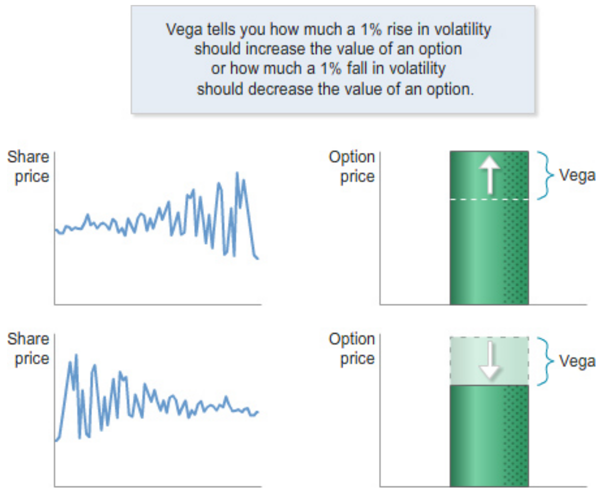
Example
If your option is trading at $1.35 and has a theta of -0.08, theoretically the option will be trading at $1.27 tomorrow, assuming no change in the stock price and other variables affecting the option's price.

Vega

Vega (also known as 'kappa') is a measure of an option's sensitivity to a change in volatility. It helps you answer the question:

If volatility changes, how might that affect the value of my option?

Vega tells you the amount by which an option's value should change, given a 1% change in the underlying stock's volatility. It is positive for long option positions, because both call and put premiums rise with increases in volatility.



At-the-money options are most sensitive to changes in volatility, so have the highest vega.

A familiarity with vega can help you understand why your option value has changed even though the stock price may not have changed significantly.

Example
If the vega of an option is 0.08, you would expect the option price to increase or decrease by around $0.08 if volatility increases or decreases by 1%.

Rho

Rho is a measure of an option's sensitivity to a change in interest rates. It helps you answer the question:

If interest rates change, how might that affect the value of my option?

Rho tells you the amount by which an option's value should change, given a 1% change in the risk-free interest rate. It is positive for call options, as increases in interest rates lead to a rise in call premiums, and negative for puts, as increases in interest rates lead to a fall in put premiums, all else being equal.

Rho is probably less important than the other Greeks, as movements in interest rates tend to have a relatively low impact on option prices.

Example
If the rho of an option is 0.015, you would expect the premium to change by around $0.015 if interest rates change by 1%.

	Sensitivity of...	to a change in...
Delta	Option price	Share price
Gamma	Option delta	Share price
Theta	Option price	Time to expiry
Vega	Option price	Volatility
Rho	Option price	Interest rates

Topic 5: Delta

Delta and multi-legged strategies

In a multi-legged strategy, each leg will have a different delta, so it will react differently to a change in stock price.

What matters is how the value of your position as a whole changes in response to a change in share price.

Strategy	Leg 1	Leg 2
1	Taken call: delta 0.6	Written call: delta -0.4
2	Taken put: delta -0.3	Written put: delta 0.5
3	Taken put: delta -0.6	Written put: delta 0.35
4	Taken call: delta 0.55	Taken put: delta -0.45

Example
Your strategy consists of:

- long one call, with a delta of 0.55, and
- short on call, with a delta of -0.35.

For a \$0.10 rise in the stock price, you would expect the taken call to increase in value by \$0.055 (increasing the value of the spread), and the written call to increase in value by \$0.035 (decreasing the value of the spread).

The overall increase in the value of the strategy is therefore \$0.02 (= \$0.055 - \$0.035).

Position delta

You can work out the net delta of your strategy by summing the deltas of the individual legs.

	Strategy 1	Strategy 2	Strategy 3
Leg 1 delta	0.60	-0.40	-0.65
Leg 2 delta	-0.45	-0.40	0.30
Net delta	0.15	-0.80	-0.35

You must remember to include the sign of the delta:

- taken calls and written puts have a positive delta
- taken puts and written calls have a negative delta.

Example
Using the previous example:

Taken call delta	= 0.55
Written call delta	= -0.35
Net delta	= 0.20

For a $0.10 rise in the stock price, you would expect your position to increase in value by $0.02.

Equivalent Stock Position

The 'equivalent stock position' (ESP) is the exposure resulting from an option position expressed in terms of shares:

ESP = option delta x number of underlying shares

Example
You buy ten XYZ call options with a delta of 0.6. Each contract covers 100 shares.

ESP = 0.60 x 100 shares x 10 contracts = 600 shares

Your call options give you exposure equivalent to owning 600 XYZ shares.

Your position may include more than one option series, and possibly a shareholding. You must take all of these into account in calculating your ESP.

Position	Delta	ESP
Long 2000 shares	1.0	2000
Long 20 puts	-0.25	-500
Short 20 calls	-0.3	-600
Net position		900

Remember that shares by definition have a delta of 1.0.

Example
You have the following position:

- hold 1000 shares
- long 10 puts with a delta of -0.3
- short 10 calls with a delta of -0.4

Your ESP is calculated as follows:

ESP shares = 1.00 x 1000 shares
= 1000 shares

ESP puts = -0.30 x 100 shares x 10 contracts
= -300 shares

ESP calls = -0.40 x 100 shares x 10 contracts
= -400 shares

Net ESP = 300 shares

Your exposure is equivalent to owning 300 XYZ shares.

Position delta is not fixed

As the stock price moves, the delta of the component legs of your strategy will change.

As a result, your position delta (and therefore ESP) will change. Your strategy may become more or less sensitive to changes in the share price.

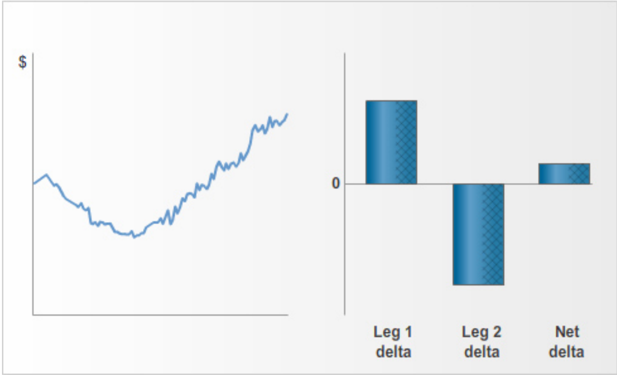
Other influences on delta

Even if the stock price does not change, your position delta may still change.

Delta changes as time passes. As expiry approaches, the delta of in-the-money options increases, and the delta of out-of-the-money options decreases.

Changes in the volatility of the underlying stock can also affect an option's delta. However a change in the share price is usually the most significant influence on delta.

As the stock price moves, your position delta will change.



Summary

- A stock's volatility is expressed as an annualised percentage figure.
- You can use this figure to calculate the stock's likely trading range over a period of days, weeks, or months.
- Implied volatility typically varies across different strike prices and can vary across different expiries. This is called 'volatility skew'.
- While stock price is the most important influence on the value of your position, changes in volatility can also significantly affect your strategy.
- If your position is a combination of taken and written options, the effect of a change in volatility can be complex, as the two legs will react differently.
- An option pricing model produces sensitivity measures known as 'the Greeks'.
- Delta is a measure of an option's sensitivity to a change in the price of the underlying shares.
- In a multi-legged strategy, each leg will have a different delta, so it will react differently to a change in stock price. What matters is how the value of your position as a whole changes in response to a change in share price.
- Delta changes as the stock price moves, time passes and volatility changes.
- An option strategy's equivalent stock position (ESP) expresses the exposure resulting from the strategy in terms of shares.

Practical examples of option strategies are given throughout these modules.

Prices used in the examples were calculated using an option pricing model, and are based on the following, unless otherwise specified:

- Underlying stock price: $10.00
- Volatility: 25%
- Risk free interest rate: 5%
- Days to expiry: 30
- The stock does not go ex-dividend during the life of the option
- American exercise style

Brokerage costs are not included in the examples. It is, however, important to take brokerage costs into account when trading options.

Please note that some payoff diagrams that appear in this course are conceptual in nature, and may not be drawn exactly to scale.