Quantitative Investment Management
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Lecture 36
Introduction to Options

Welcome back. So, let us continue with the example about the pricing or the valuation of a forward contract at a date subsequent to the date of it is interception.

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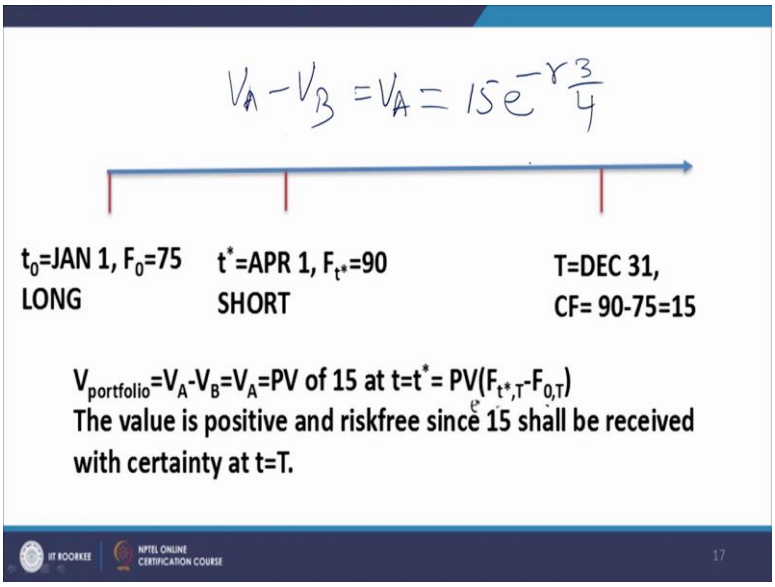

We consider a contract let us call it contract A that is instituted on January 1 and that entails the delivery of our new installers at a price of 75 on 31st of December which is the date of maturity of this contract A. So, 1 Dollar is to be delivered under this contract against a payment of INR 75. Let us say we have to value this contract as on April 1 of the same year and let us say at that point in time the forward price of the US Dollars has gone up from 75 to 90 for delivery at the as on 31st December in other words if we enter into a forward contract let us call it contract B if we enter into a forward contract as on 1st April of the year for delivery as on 31st December of the same year that would entail a price of INR 90 for 1 Dollar of the being the underlying.

Now, what we have to do is we have to value the contract A as on April 1 of that year. So, what we do is as I mentioned before the break we construct a Portfolio comprising of a long position in A and a short position in B the value of this Portfolio will be V A minus V B and because V B is equal to 0 the value of a contract on the date of it is institution is always 0. So, this is equal to V A.

And now let us look at the payoffs from the contract. The payoffs from the contract because we have a long position in A that would mean what that means we will receive the Dollar by paying INR 75 the short position in B means what we will deliver the Dollar at INR 90 in other words the Dollar content cancels out as far as the Portfolio is concerned and we I end up with a net surplus of INR 15.

So, the payoff from the contract as on 31st December is INR 15. So, assuming that both the contracts are default free we discount this value at the risk-free rate to bring it back to April 1 and that will be the value of our contract here. So, this will be equal to 15 e to the forward minus r into whatever the time period is in the work case it is 9 by 9 months.

So, that will be 3 by 4th of a year. So, this is an example of how the value of a forward contract subsequent to it is rate of inception may be calculated and clearly it may or may not be 0 that is the important thing. So, it depends on the price or the forward price that is prevailing on the data valuation of the contract.

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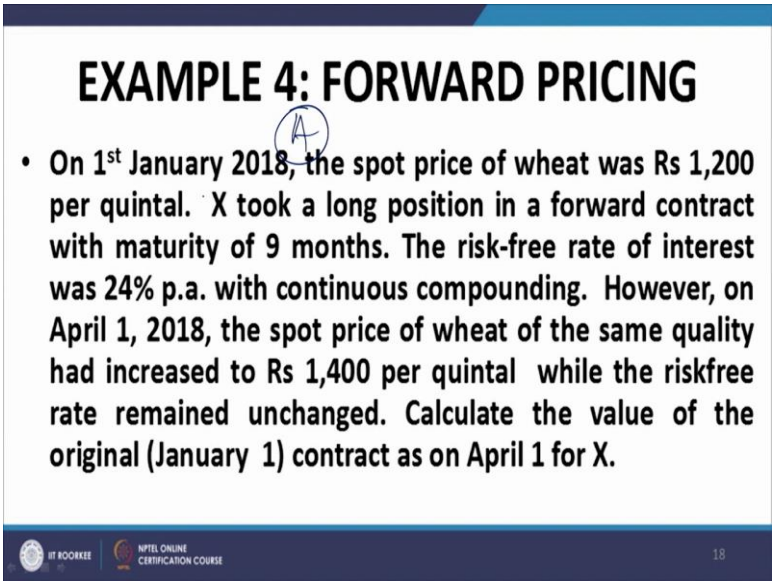

Let us do a formal example on this, on 1st January 2018 the spot price of wheat was rupees 1 thousand 2 hundred per quintal. X took a long position in a forward contract with maturity of 9 months. There is free rate of interest is 24 percent per annum with continuous compounding however on April 1, 2018 that is 3 months after the institution of the contract the spot price of wheat of the same quality had increased to rupees 1400 per quintal at t equal to 0 it was 1200 at t equal to 3 months and that is 1st April it was 1400 for quintal. While that is free rate remains unchanged. Calculate the value of the original January 1 contract let us Call it contract A.

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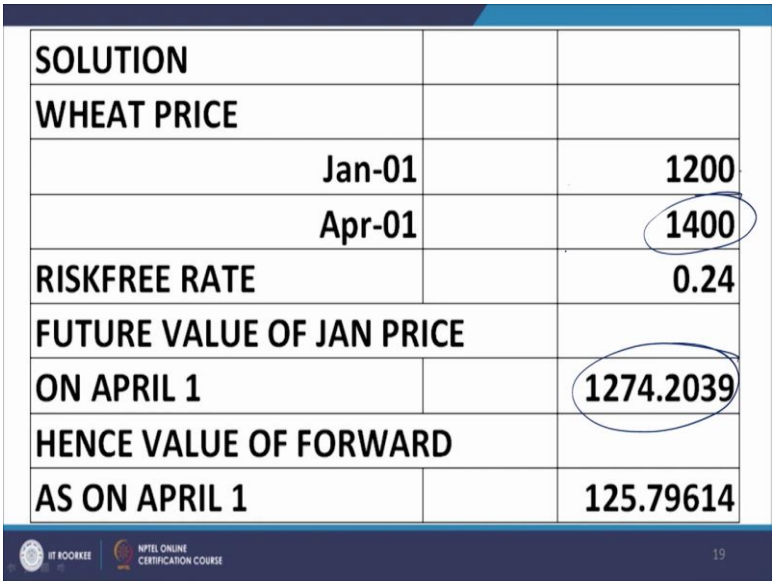

So, calculate the value of contract A as on 1st April of the year that is 2018. This is quite simple we work out the future value of this contract A as on a date of evaluation that turns out to be 1274.2035 and we determine the value of the contract and that is 125.79614.

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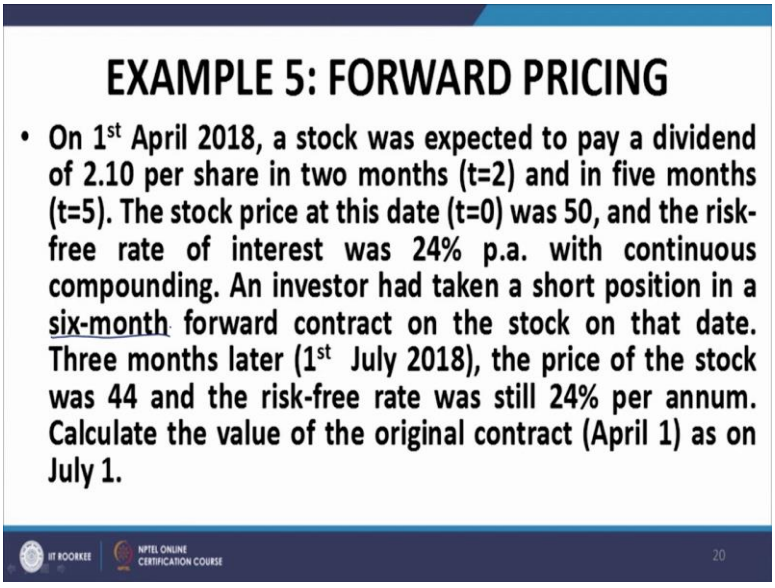

Another example on 1st April 2018 a stock was expected to pay a dividend of 2.10 per share in 2 months and in 5 months same amount 2.10 or 2 t equal to 2 months and 2.10 at t equal to 5 months the stock price on the state that is t equal to 0 was 50 and the risk free rate of interest for 24 percent per annum continuously compounded. An investor has taken a short position in a 6 month forward contract on the stock on the date 3 months later 1st January to

our 2018 the price of the stock was 44 and the rest period rate was till 24 percent per annum continuously compounded calculate the value of the contract.

So, there is an important catch here the important catch is here is that and the contract is instituted on 1st April 2018 and that means let us take that as t equal to 0 the dividend payments are at t equal to 2 months and t equal to 5 months. So, that was the 2 1st of June and 1st of October. Now, the maturity of the contract is 6 months and maturity of the contract is given as 6 months. So, the important thing here is the dividend at t equal to 2 there are 2 dividend points t equal to 2 months, t equal to 5 months that is 1st June and 1st October and the maturity of the contract is 6 months from 1st April. So, that is as on 30th of September or 1st of October.

Now, that means and we have to value the contract as on 1st July. When we value the contract at 1st of July one of the dividend payments would have expired in other words the valuation of the contract as on 1st July will be on the basis that the remaining life of the contract involves only 1 payment of dividend not 2 payments of dividend because 1 payment of dividend would already have taken place between 1st April and 1st July that is on 1st of 1st of June. So, that is the catch here in this problem let us solve this problem.

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SOLUTION					
TIME		0.0000	2.0000	5.0000	6.0000
STOCK PRICE		50.0000			
INTEREST RATE(24%)		0.2400	0.0400	0.1000	0.1200
DISCOUNT FACTOR			-0.0400	-0.1000	
			0.9608	0.9048	
DIVIDEND			2.1000	2.1000	
PV OF DIVIDEND			2.0177	1.9002	1.1275
		3.9178			
NET STOCK PRICE AT T=0		46.0822			
FORWARD PRICE AT T=6		51.9575			

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So, this is the time frame this is the current spot price and this is the risk free rate and these are the present values of the 2 dividend payments t equal to 2 months and t equal to 5 months the total dividend payment is this much. So, the Net stock price at t equal to 0 is this means 46.08 and the forward price at 1st April is 51.

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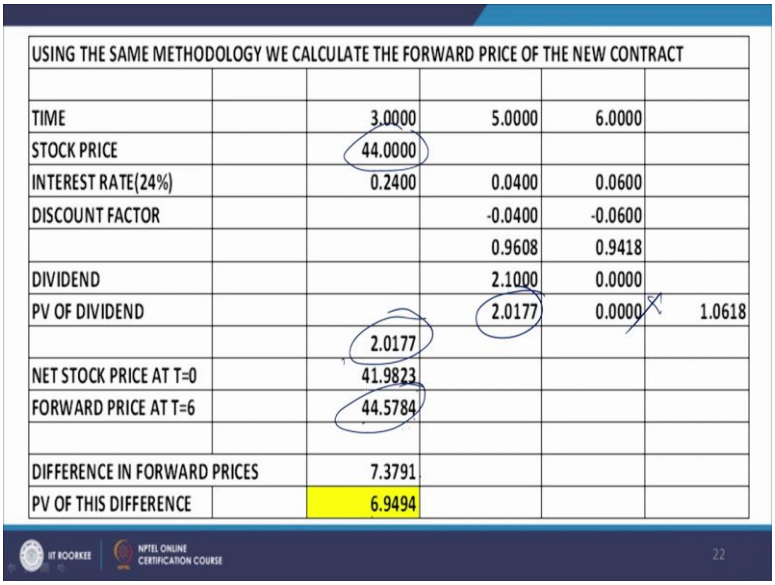

Now, we look at the forward price as on 1st of July that is the date of valuation of the contract, when we work out the price as on date of valuation of the contract the important point here is that only one dividend stream will remain this the second dividend stream is 0 that is the important part because that dividend, the 1st dividend stream that is the dividend stream at t equal to 2 months would already have paid out before the date of valuation and will not contribute to the forward price when we work out the forward price as on the date of valuation that is the catcher that is shown here also then hence the present value of dividend works out to 2.0177 the current spot price is 44 therefore the net price is this 41.9823 that is S 0 minus D 0 and the forward or the future value of this price at the date of maturity of the contract that is 1st October is 44.5784.

So, the differential in prices is 51.95 is 75 minus 44.5784 and the present value of this amount is equal to 6.9494 with the present value on which date on the date of valuation. The present value on the date of violation and please note this is positive why because the investor has a short position in this. So, notwithstanding the fact that there is a decline in price he tends to gain because he has a short position in the in the contract.

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So, that is all that is required or relevant and so far as forwards are concerned let us start with Options, what is an Option Contract? An Option is a contract whereby the holder of the contact acquires a Right this is the catch this is the important part. Right propagate a privilege to buy obelic sell a certain asset on a certain date at a certain price. So, the important thing is this word Right. So, if one of the parties are the Right and it is quite natural that the other party has the obligation because if I if A exercise is the Right.

Then B is under obligation to honor his leg of the contact V does not have the Right the BV if A is exercising B will also exercise that is not the point the point is if A exercises then B must deliver or B must honor his leg of the contract and if a does not exercise well it is fine for B it is he goes Scot free.

Now, the important the second important thing is because they are not on equivalent pedestals A has the right B does not have a right therefore A has to compensate B for the with a certain amount of money which is Called the Option price or the Option premium such that he acquires that Right from B and B in compensation of the amount of Premium or a price is willing to take up the obligation that is how the Option Contract operates.

So, an Option is a contract whereby the holder of the contract acquires a Right to buy obelic sell a certain asset by obelic on a certain date for a certain price. Accordingly, the writer of the Option, the 1st part is said to be the holder of the Option, the second part is said to be the writer of the Option, the 1st part is said to be long in the Option, the second part is said to be short in the Option, the 1st party is said to have bought the Option, the second part is said to have sold the Option.

Accordingly, the writer of the Option has the Obligation. So, this is the important word, here we have a Right, here we have an Obligation to sell obelic buy the asset by your own on the set date at the set price if the holder decides to exercise the Option. So, this is another catch, if the holder decides to exercise the Option, the choice, the description, the privilege is with the holder of the Option whether he wants to exercise the Option or he does not want to exercise the Option. The party B that is the party who has written the Option party is short in the Option has no discretion.

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Quick reference to terminology an Option which has a single maturity rate that is which matures in the particular date in other words the Option can be exercise only on a particular date which is Called the maturity rate of the Option is said to be an European Option. An Option which can be exercise on any day up to the date of maturity is said to be American.

Underlying Asset the asset which forms the substratum of the Option Contract that is the asset which is which can be bought or which can be sold at the certain price on a certain date or by a certain date for that matter is said to be the Underlying Asset. It forms a substratum of the contract, it is the item entity that changes hands as a consequence of the Option Contract if the Option holder decides to exercise the Option.

Call and Put Options, Call Option is the right to buy Put Option is the right to sell if you are long in the Call Option you have a right to buy the underlying asset at a predetermined price on a predetermined date both pre-determined price and predetermined date are part of the Option Contract and are determined at the Inception of the Option it is not that the you can buy the asset at the then prevailing price that is not the case you can buy the asset at the price

that is agreed upon at the t equal to 0 debt which impact is Called the excise price or the strike price under the Option Contract on the date of maturity or by the date of maturity which is Called the maturity rate of the Option or the exercise date of the Option.

So, Call Option right to buy Put Option right to sell. Strike date, the date on which you can exercise the Option in the case of European Options, the date up to which you can exercise the Option in the case of American Options. Holder of the Option the person who has the right. The Writer of the Option the person who has the Obligation. Long position the party was bought the Option. Short position the party was written the Option.

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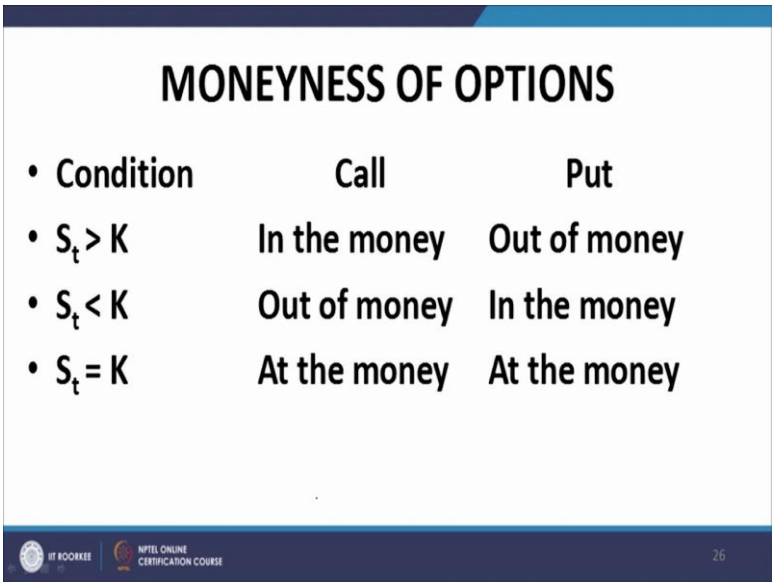

Moneyness of Options if at a particular point in time let us consider for that matter let us 1st let us be concrete let us consider a Call Option, Call Option is the right to buy. Now, suppose on a particular date S t what is S t. Let me explain the notation for a minute S t is the instantaneous stock price instantaneous price per unit of the underlying at t is a given point in time an arbitrary point in time and the spot price or the price in the sport Market of the underlying asset at that point in time t is called is represented by S t. K is the excise price of the under the Option Contract that is the price at which you can buy or sell as the case may be in the case of Call or Put Options under the Option Contract.

So, if S t is greater than K if any particular point in time at any particular point in time small t S t is greater than K that is the prevailing stock price in the spot market is greater than the exercise price of the Option the Option is said to be in the money if it is a Call Option the Option is said to be out of the money if it is a Put Option if S t is less than K that is the instantaneous stock price is less than k then the Option is said to be out of the money if it is a

Call Option it is said to be in the money if it is a Put Option and if S t is close to K or the S t is equal to K the Options are set to be at the money.

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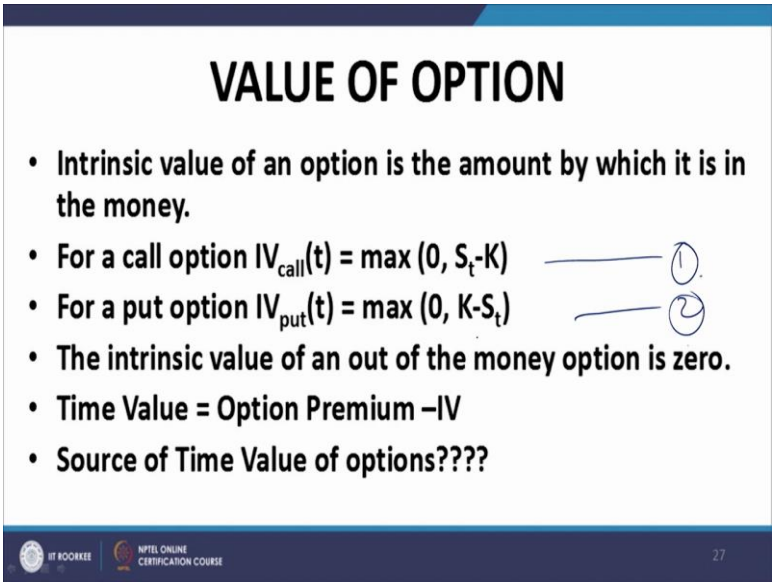

Value of an Option, the Value of an Option can be is split up into 2 parts number 1 is the intrinsic value of the option and number 2 is the time value of the option. The intrinsic value of an option can be defined by equations number 1 and 2 for the call option and put option respectively. So, intrinsic value of a call option is the maximum of 0 comma S t minus K that is if S t is less than K the intrinsic value is 0, if S t is greater than K the intrinsic value is as t minus K. Similarly, in the case of a put option, if S t is less than K the intrinsic value is K minus S t, if S t is greater than K the intrinsic value is 0 this is the case of a put option and in the call option equation number one verse.

Now, the second part is the Time Value of the Option, the market price of the option is usually greater than the intrinsic value and the differential between the market value of the option, the market price of the option and it is intrinsic value represents the time value of the option.

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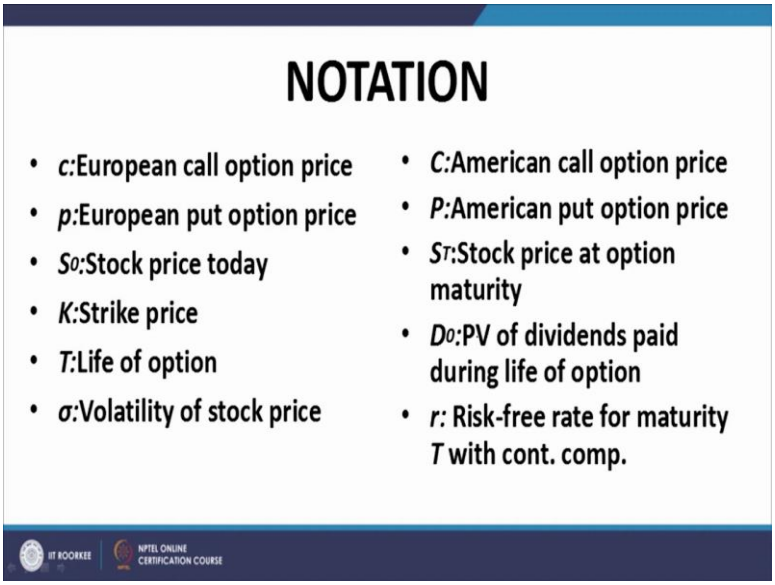

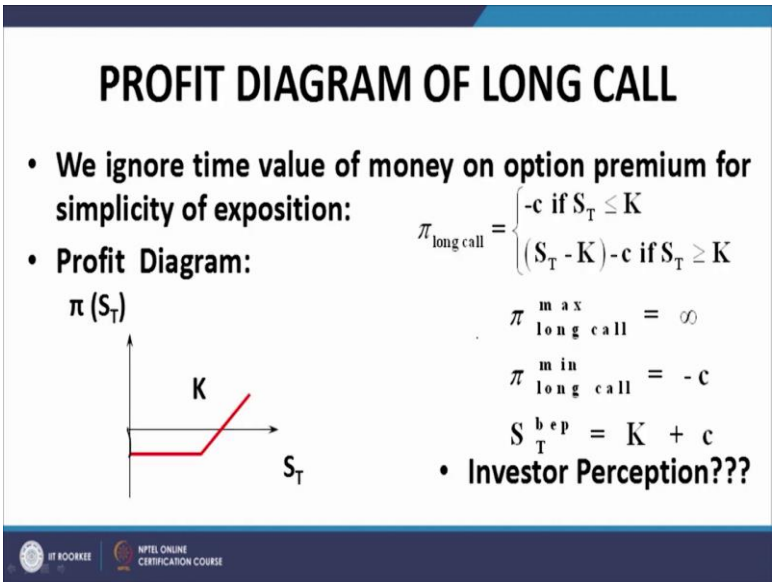

The time value of the Option arises somewhere will come back to it but before that let us finish off with the notation small c represents the European call option price, small p represent European put option price, S 0 is the stock price at t equal to 0, K is the strike price I mentioned that, T is capital T is the maturity of the option, Sigma is the volatility of stock price we shall be talking more about it, capital C is the American call option price, capital P is the American put option price, S t is the stock price at maturity capital T, D 0 is the present value of dividend paid during the life of the Option we have encountered that in the context of forwards, r is the Risk-rate of the Risk-free rate of interest with continuous compounding and maturity equal to capital T.

Now, profit diagrams of long Call before that let me go back a bit and explain the relevance of time value of an option you see very often it happens it is true that the option on an underlying asset derives it is value because of the uncertainty in so far are it is exercisability is concerned there is always, for example let us take the call case of a call option let us say at a particular point in time let us say as in a particular day say 1st of April and the stock price is 50 and the exercise is 60.

So, obviously the option is out of the money even if you exercise the option you will not get any profit because the market price is lower than the exercise price. So, what is the point in buying at 60 if the market price is at 50. Suppose the maturity of this option is on 1st of May that is a an in 1 month from today from today's 1st of April. Now, there is always a possibility that not restoring the fact that as of today the intrinsic value of the option is 0 because the market price is lower than the exercise there is always a possibility that as on the date of maturity that is as on 1st of May.

The market price of the stock could go above the excise price and therefore the Option which is not profitable as of today may become profitable at a future date. If that possibility that eventuality has a certain finite probability and it is the discounting of that probability in some sense that gives rise to the time value of the option see if you work out the intrinsic value of this option at this point it is clearly 0 because the option is not worth exercising but however because the option has the possibility of earning you a profit as on the debt of maturity if the stock price goes above the exercise price of 60 that possibility when translated to money terms will give you a certain add-on value to the price of the option or to the value of the option and as a result of it the current market price of this option would be greater than 0 and this success is basically the time value of the Option .

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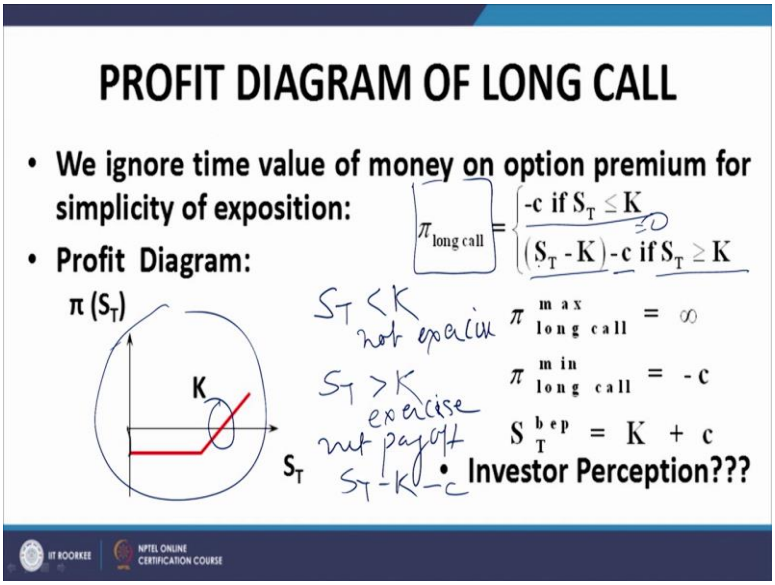

So, let us now talk about the profit diagram of a Long Call I just mentioned that if S T is greater than K then the option would be would be in the money and if it is less than K the option would be out of the money. So, let us understand the rational for this what is the Call Option, the Call Option is the right to buy the underlying asset we are talking about European Options. So, S T is let us assume that S T is less than K what does it mean it means that the market price is lower the excise price is higher.

So, why should I invoke the option and buy at the higher price if I want to acquire the asset I did rather buy it in the Market at S T and let the option lapse. So, the bottom line is that if S T is less than K the option will not be exercise if it is a call option of course but if S T is greater than k then what happens, suppose the market price is 70 market price has gone up to from 50 up to 70 and the exercise price as 60 what will I do as a rational investor I will excise the option buy the asset at 60 and immediately sell it in the Market at 70 and pocket a profit of 10 unit is of money.

So, that is that is what would happen if S T is greater than K in this case the option will be exercised and what is the net pay of S T minus K and what is the net profit S T minus K minus the option price that we pay to acquire the option. So, the payoff is S T minus K the profit is S T minus K minus c and the important thing is please note that there is a Time differential involved between the payment of the price and the and the payoff from the option but because the option price is very small it this time value on this time differential is usually ignored when we prepare the payoff diagrams and we write the payoff S T.

We write the profit as S T minus K minus c instead of S T minus K minus c, e to the forward R T because we should be taking the future value of c because c is paid at t equal to 0 or at an earlier date when we acquire the option and obviously on the date of maturity we should be considering the future value of the of the a premium that we pay but normally that is very small that is insignificant and therefore we ignore that and therefore the profit is S T minus K minus c and the payoff is S T minus K if S T is greater than K and if S T is less than K.

The option will not be exercise the payoff will be 0 and the profit will be equal to minus c because the amount of premium that we have paid is a loss for you it is the sun cost and therefore it will be it will be considered as minus c and that is the that is the rational of this profit function Pi of long Call is equal to minus c if S T is less than K and S T minus K minus c if S T is greater than K what is the and this is the plot this is the payoff diagram and this is the profit diagram rather as you can see here and what are the Breakeven points you can see here this is the Breakeven point. what is the Breakeven point?

The Breakeven point is the point at which a situation of no profit no loss emerges from the strategy and this is given by K plus c as you can see here in this diagram it can be calculated geometrically, it can be calculated from the profit function as well by equating this to 0 if you equate the profit to 0 you get S T is equal to K plus c as the Breakeven point and some other features the profit under the strategy of a Long Call is unlimited whereas the loss is restricted to the amount of premium that we have paid for acquiring the Option.

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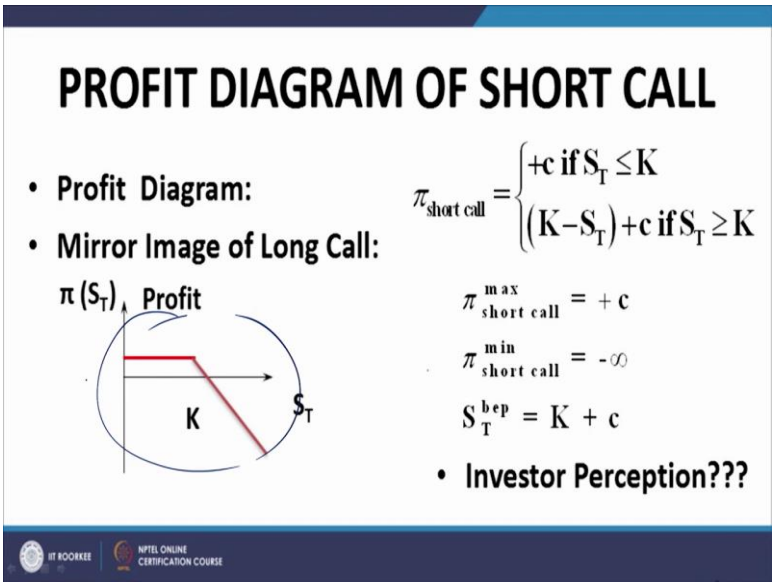

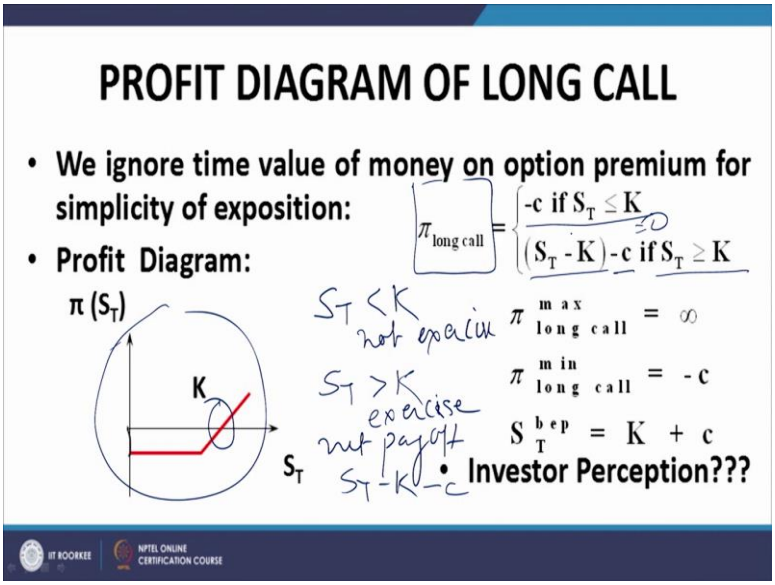

As far as the Short Call is concerned it is the inverse is the mirror image of the Long Call and you can see you can make that out from this profit diagram as and you can also make it out from the from the profit function here the maximum profit that you have at the premium that to receive because obviously you cannot go beyond that there will be no situation in which you will get a profit above the premium the maximum loss is unlimited corresponding to the maximum profit of the party is long in the option and the Breakeven point is again K plus c.

What is the investor perception by the way what is the investor perception if you are having a Long Call strategy that is very interesting that needs to be explored? Clearly you see from this diagram that higher the price of the underlying asset at maturity of the option higher is your profit. So, clear from this function as well S T minus K higher the value of S T because K is constant K is exercise wise that is contained in the offer document that is fixed once and for all and c is also the price that you paid.

So, c also does not go into the picture that has already been paid. So, the only variable as on the date of maturity is S T and you find there from the profit function as well as from the diagram that higher the value of S T beyond K higher is the profit, up to K the profit is fixed or the option will not be exercised and therefore it is a loss of the premium but once the stock price ends up at maturity of the option at any value above K you tend to gain by doing what by buying the asset at K and selling it in the Market at S T.

So, the net result is that what why would or when would an investor enter into this strategy an investor would enter into the strategy when he feels that the market is likely to be extremely bullish they are the underlying asset is going to be sold or is likely to result in a significant

price rise as on the date of maturity is extremely bullish about the prospects of the underlying asset as on the date of maturity of the option.

The inverse is the case here what will happen if the stock price goes below the exercise price or the stock price remains below the exercise price as on the date of maturity of the option the invest, the Option Holder will not exercise the option and if the option order not does not exercise the option the investor write the Option Writer I am sorry the investor on the Option Writer will pocket the premium arising out of the sale of the option to the Long Option or the Option Holder

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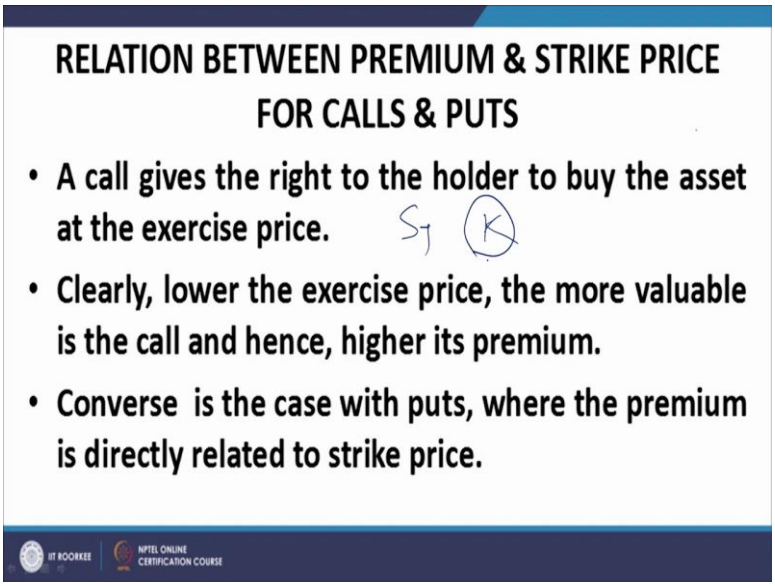

Relation Between Premium and Strike Price for Calls and Puts this is very interesting you see what does what does the Call Option give you the Call Option gives you a right to buy the asset at K irrespective of what S T is. So, clearly higher is the higher is the value of K that means you have to sell out a higher amount for buying 1 unit of the underlying asset therefore lower would be the premium higher the value of K higher is the exercise price the higher is the price is that you are going to pay for acquiring the asset under the Option Contract.

Then therefore lower would be the premium on that in other words if you have 2 options A and B 2 calls A and B, A entails on the same underlying, A entails buying the asset at 50, B entails buying the asset under at 100, clearly the cost of A would be higher than the cost of B the cost of B would be lower than the cost of A. What about S T? If S T is higher naturally the price of the Option would be higher because higher is the pay of S T minus K.

So, that as far as the call is concerned a call gives the right to the holder to buy the asset at the exercise was clearly lower the excise price higher is the value of the call more is the worth of the call, higher is the premium and conversely as far as puts are concerned when the premium, premium is directly related to the exercise price, lower is the exercise price, lower is the price at which you can sell they asset and therefore lower is the value of the option.

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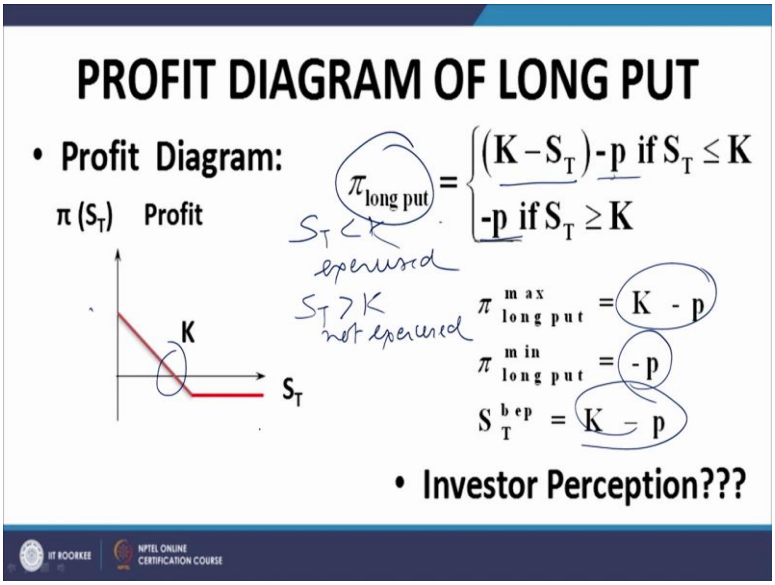

Profit Diagram of a Long Put. Now, what is the Long Put. a Long Put gives you the right to sell the asset at the excise price on the debt of maturity of the option where so far please note we are considering only European Options. So, let us look at the situation S T is less than K. If S T is less than K what are we saying we are saying that the market price is lower than the excise price. So, because the market price is earned and what is the Put Option the Put Option is the right to sell the asset.

So, if you sell the asset in the market we are going to get S T if you sell the asset under the Put Option Contract you are going to get K and please note by assumption S T is less than K. So, obviously you would rather exercise the option sell it under the Option Contract instead of not exercising the option in other words if S T is less than K the option would be exercised and if S T is greater than K you would rather sell it in the market because the market price is higher than invoke the option and sell it at the exercise price.

So, not exercised and what is the net payoff if it is exercise well you buy the asset industry in the market and sell it at K in the market capacity is less than K if S T is smaller buy it in the market buy the asset in the market and sell it under the higher price under the under your holding of the Put Option under your long position in the Put Option at K. So, you get you

pocket a profit of what you pocket up a payoff of K minus S T. So, what do we have the profit of a long Put is K minus S T minus the cost of acquiring of the option, the option premium which will attach minus p.

So, the profit that arises if S T is less than K is because buying the asset in the Market at S T selling it at the higher price of K getting a payoff of K minus S T less the price you paid for acquiring the option. So, the net price net profit is K minus S T minus p and obviously if S T is greater than k you sell the asset in the market you do not exercise the option and because you do not exercise the option you lose the price that you paid for the option you lose the premium that you paid for the option.

So, the profit is minus p and you can see from the diagram the maximum profit is curtailed at what maximum profit is equal to K minus p the maximum and what about the maximum loss the maximum loss is equal to minus p and the Breakeven point is equal to K minus P this is the Breakeven point. So, this is K minus p this is the maximum profit this is equal to K minus p and the maximum loss is equal to minus p.

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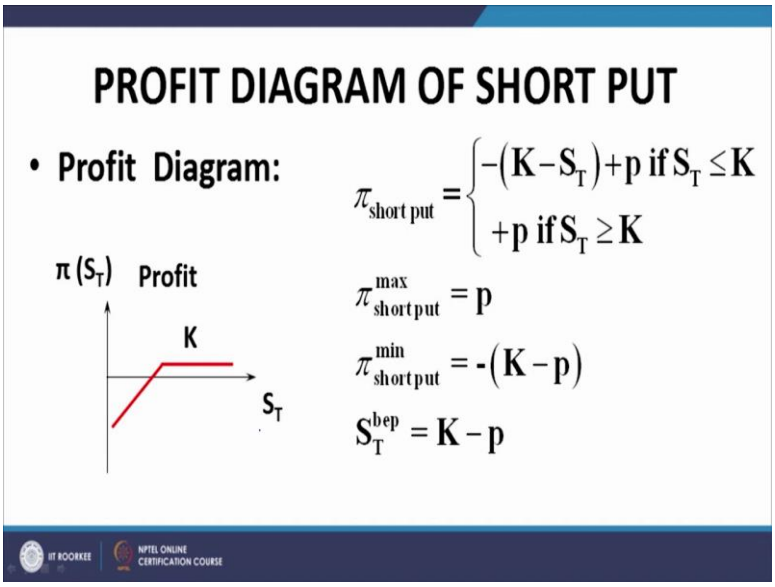

And this is the corresponding diagram for a Short Put I will not devote time to it, it is pretty much the same way as we had for a Short Call.

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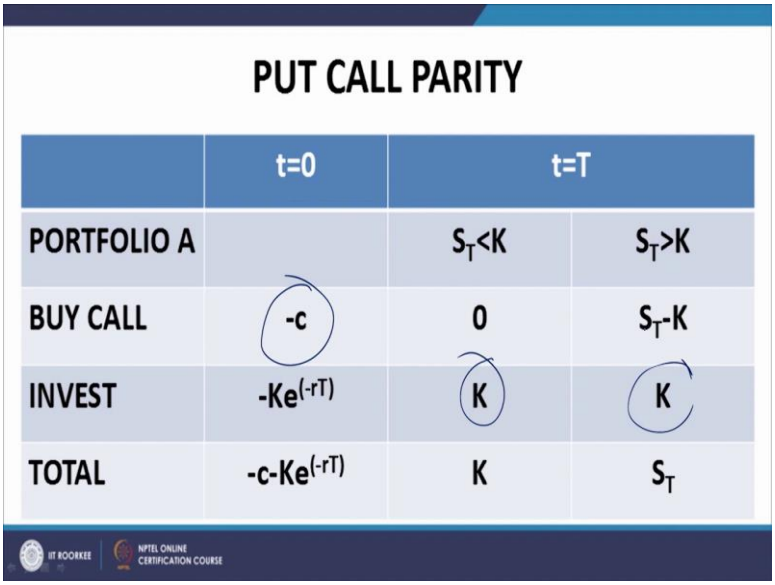

So, we consider a very important relationship which is called Put Call Parity let us look at a situation and Put Call Parity let me give you the backdrop first, Put Call Parity aims to arrive at an equivalence between certain quantities arrive at a relationship of the prices of a Call Option and a Put Option on the same underlying same maturity same exercise if you have 2 options one is the Call Option, one is the Put Option on the same underlying same maturity same exercise price then is there any relationship between them.

Let us explore that for that purpose we construct 2 Portfolios Portfolio A and Portfolio B in Portfolio A what we do we take a long position in the Call Option because we take a long position in the Call Option the cash outflow at t equal to 0 is equal to minus c and the payoffs are going to be if S T is less than K the payoff is going to be 0 and if S T is greater than K the payoff is going to be S T minus K we also invest a certain amount of money how much do we invest, we invest k e to the forward minus r T and on maturity you can see here on maturity of the option will get K as a cash inflow irrespective.

Now, this cash inflow K arising out of the investment of the money at t equal to 0 equal to the present value of K is independent of the state of nature in other words you will receive this K irrespective of what value S T takes irrespective of whether S T takes the value less than K or S T to takes the value greater than K. So, the net payoff of this combination a Long Call and an investment equal to the present value of x s plus is equal to K if S T is less than K and is equal to S T if S T is greater than K

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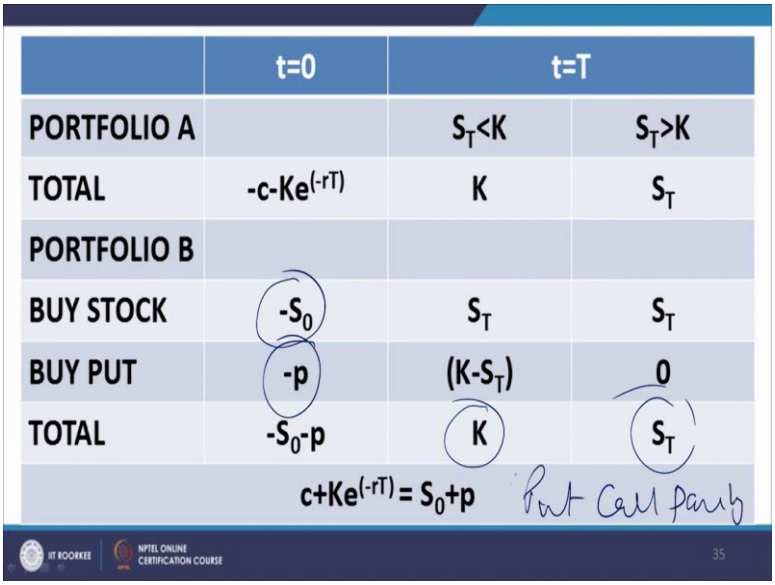

	t=0	t=T	
PORTFOLIO A		$S_T<K$	$S_T>K$
TOTAL	$-c-Ke^{(-rT)}$	K	S_T
PORTFOLIO B			
BUY STOCK	$-S_0$	S_T	S_T
BUY PUT	-p	$(K-S_T)$	0
TOTAL	$-S_0-p$	K	S_T

$c+Ke^{(-rT)} = S_0+p$ Put Call Parity

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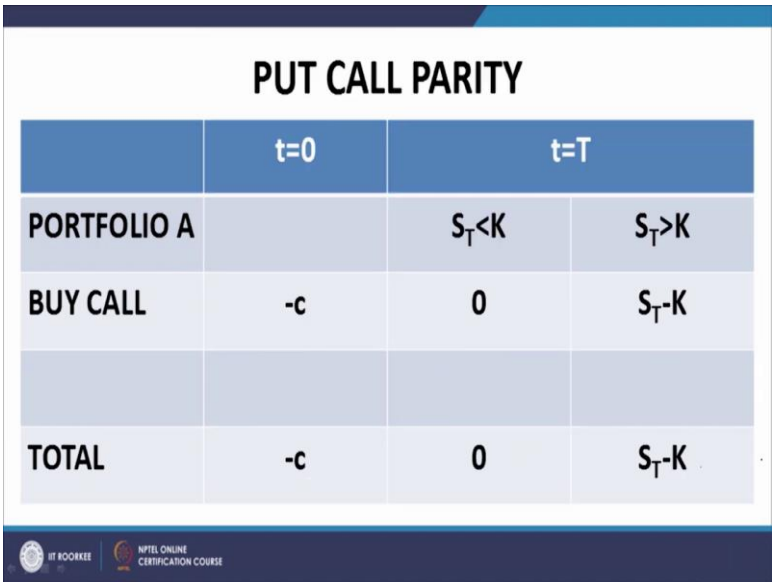

PUT CALL PARITY

	t=0	t=T	
PORTFOLIO A		$S_T<K$	$S_T>K$
BUY CALL	-c	0	S_T-K
TOTAL	-c	0	S_T-K

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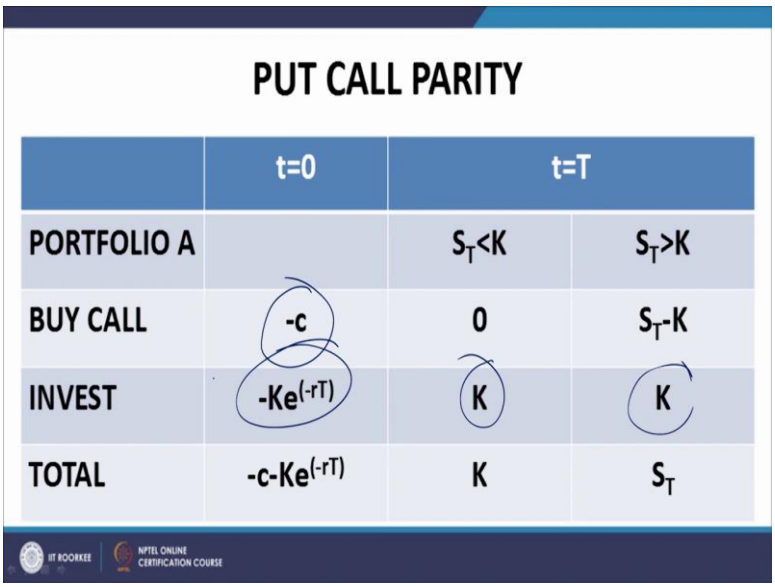

PUT CALL PARITY

	t=0	t=T	
PORTFOLIO A		$S_T<K$	$S_T>K$
BUY CALL	-c	0	S_T-K
INVEST	$-Ke^{(-rT)}$	K	K
TOTAL	$-c-Ke^{(-rT)}$	K	S_T

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Let us look at the Portfolio B the Portfolio A total I have written up here just to make a comparison easy for Portfolio B we buy, we buy 1 unit of the stock that costs you S 0 at t equal to 0 because you buy the stock it is a cash outflow. So, it is shown with the minus sign here. So, we buy 1 unit of the stock at t equal to 0 and the value of the stock at maturity will be S T and this S T will be independent of whether S T is less than K or greater than K it will throughout the S T notwithstanding that what S T turns out to be less than K or greater than K.

We also buy a Put Option therefore we pay a price for that and the payoff from a Long Put is given by K minus S T if S T is less than K and 0 otherwise and you find here that the net payoff at maturity it turns out to be K of S T is less than K and S T if S T is greater than K. Now, clearly the payoffs from Portfolio A and Portfolio B are identical in each state that S T can occur if S T is less than K both of this Portfolios A and B give you a payoff of K if S T is greater than K both of these Portfolios give you a payoff of S T.

So, the payoffs are absolutely identical, there is no intermediate cash flow between t equal to 0 and t equal to capital T and these payoffs are certain and that means what that means that the prices of these Portfolios much necessarily be the same by the law of 1 price that gives us this relationship which is Called Put Call Parity. Now, from where this factor of investment comes into play I shall explain in the next lecture thank you.