1. Volatility Index

Volatility Index is a measure of market's expectation of volatility over the near term. Usually, during periods of market volatility, market moves steeply up or down and the volatility index tends to rise. As volatility subsides, volatility index declines. Volatility Index is different from a price index such as NIFTY. The price index is computed using the price movement of the underlying stocks. Volatility Index is computed using the order book of the underlying index options and is denoted as an annualised percentage.

The Chicago Board of Options Exchange (CBOE) was the first to introduce the volatility index for the US markets in 1993 based on S&P 100 Index option prices. In 2003, the methodology was revised and the new volatility index was based on S&P 500 Index options. Since its inception it has become an indicator of how market practitioners think about volatility. Investors use it to gauge the market volatility and base their investment decisions accordingly.

2. India VIX*

India VIX is a volatility index computed by NSE based on the order book of NIFTY Options. For this, the best bid-ask quotes of near and next-month NIFTY options contracts which are traded on the F&O segment of NSE are used. India VIX indicates the investor's perception of the market's volatility in the near term i.e. it depicts the expected market volatility over the next 30 calendar days. Higher the India VIX values, higher the expected volatility and vice-versa.

3. India VIX :: computation methodology

India VIX uses the computation methodology of CBOE, with suitable amendments to adapt to the NIFTY options order book.

The formula used in the India VIX calculation is:

$$\sigma^2 = \frac{2}{T}\sum \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2$$

where:

σ India VIX/100 ⇨ India VIX= σ x 100

T Time to expiration

K_i Strike price of i^{th} out-of-the-money option; a call if $K_i > F$ and a put if $K_i < F$

ΔK_i Interval between strike prices- half the distance between the strike on either side of K_i:

* *"VIX" is a trademark of Chicago Board Options Exchange,* Incorporated ("CBOE") and *Standard & Poor's has granted a license to NSE, with permission from CBOE, to use such mark in the name of the India VIX and for purposes relating to the India VIX.*

$$\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$$

(Note: ΔK for the lowest strike is simply the difference between the lowest strike and the next higher strike. Likewise, ΔK for the highest strike is the difference between the highest strike and the next lower strike)

R	Risk-free interest rate to expiration
$Q(K_i)$	Midpoint of the bid ask quote for each option contract with strike K_i
F	Forward index taken as the latest available price of NIFTY future contract of corresponding expiry
K_0	First strike below the forward index level, F.

Some of these symbols are further explained below.

3.1. Time to expiration (T)

India VIX calculation measures the time to expiration in years, using minutes till expiration. The time to expiration is given by the following expression:

$T = \{M_{\text{Current day}} + M_{\text{Settlement day}} + M_{\text{Other days}}\}$/ Minutes in a year

Where,

$M_{\text{Current day}}$ = Number of minutes remaining until midnight of the current day (from computation time upto 12.00 am). In the hypothetical example provided in the subsequent pages, it is 3.30 pm up to 12.00 am

$M_{\text{Settlement day}}$ = Number of minutes from midnight until closing hours of trading (i.e. 3:30 p.m.) on expiry day

$M_{\text{Other days}}$ = Total number of minutes in the days between current day and expiry day excluding both the days

In the hypothetical example provided in the subsequent pages, the near month option has 9 days and next month option has 37 days to expiration. Accordingly, the time to expiration (T_1) for the near month and (T_2) for the next month works out to:

T_1 = {510 + 930 + 11520) / 525,600 = **0.02466**

T_2 = {510+ 930 + 51840) / 525,600 = **0.10137**

India VIX uses put and call options in the near and next month expiration, in order to bracket a 30-day calendar period. It may be noted that CBOE VIX rolls to the next and far month with less than a week to expiration. However, with 3 trading days left to expiry, India VIX "rolls" to the next and far month.

3.2. Risk free Interest Rate (R)

The relevant tenure of NSE MIBOR rate (i.e. 30 days or 90 days) is being considered as risk-free interest rate (i.e. R_1= 0.0390 and R_2 =0.0465, in case of the hypothetical example considered subsequently) for the respective expiry months of the NIFTY option contracts.

3.3. Determination of forward index level, F

Volatility index is computed using mainly the quotes of the out of the money (OTM) options. The strip of OTM option contracts for computing India VIX could be identified if the at-the-money (ATM) strike is identified. In case of CBOE, the forward index level is arrived at by using the strike price at which the absolute difference between the call and put prices is minimum. NSE has an actively traded, large and liquid NIFTY futures market. Therefore the latest available traded price of the NIFTY futures of the respective expiry month is considered as the forward index level. In the hypothetical example given in the subsequent pages, the latest traded price of NIFTY future for near month (F_1) is taken as 5129 and next month (F_2) is 5115. This helps in determining the ATM strikes and thus the OTM strikes for the purpose of computation of India VIX.

3.4. Computation of K_0

K_0 is the strike price just below the forward index level. This is considered as the at-the money strike (K_0). In the hypothetical example discussed below, given the value of F_1 and F_2, **K_0 = 5100** for both near and next month contracts. The next step is to consider the order book for selecting the strip of OTM options for both near and next month.

4. Computation of India VIX using an example

Consider the following extract of the best bid and offer of the order book of various strikes available for trading in respect of near month NIFTY options. Similar extract shall be taken for the next month as well. To explain the methodology of selection of the strikes, application of cubic spline, etc., the example is initially worked out with the near month options.

Strike	Call Bid (Rs.)	Call Ask (Rs.)	Put Bid (Rs.)	Put Ask (Rs.)
3800	1290.10	1314.25	0.40	0.50
3900	1192.95	1212.80	0.35	0.80
4000	1103.00	1107.95	0.70	0.85
4100	1005.00	1017.10	0.80	1.10
4200	894.95	913.90	1.00	1.20
4300	800.00	809.95	1.20	1.70
4400	696.15	709.50	1.90	2.00
4500	601.25	609.55	3.30	3.45
4600	500.70	520.00	4.45	4.50
4700	410.00	416.55	7.70	8.00
4800	316.00	321.05	13.20	13.40
4900	226.00	228.00	22.50	22.65
5000	144.50	145.00	40.40	40.50
5100	79.00	79.10	74.40	74.50
5200	34.75	35.00	129.00	129.95
5300	11.50	11.55	200.55	206.00
5400	3.60	3.65	286.00	307.00
5500	1.70	1.95	340.00	396.00
5600	1.00	1.35	481.00	507.35
5700	0.70	1.00	577.35	606.65

4.1. Selection of option contracts to be used in the calculation

As stated earlier, India VIX is computed using mainly the quotes of the OTM options. All call options contracts with strike prices greater than K_0 and all put option contracts having strike prices less than K_0 are therefore considered for this purpose. In the example considered above, in respect of the near month, quotes were available for strike prices from 3800 to 5700 with a strike price interval of 100. So in respect of the call options, the quotes of seven strike prices namely, 5100, 5200, 5300, 5400, 5500, 5600 and 5700 (including the ATM strike) are considered for the computation. Similarly, in respect of put options, quotes of 14 strikes from 3800, 3900, etc. to 5100 (including the ATM strike) are considered. Similar exercise shall be done for the next month options as well.

4.2. Computation of Mid-price $Q(K_i)$

As seen above, for computation of India VIX, $Q(K_i)$, the midpoint of the bid ask quote for each option contract with strike K_i , is required. In respect of the ATM strike, the average of the mid prices of both call and put options are considered. Before proceeding further with the computation of India VIX, it is checked to see whether the quotes are available/ appropriate.

The strikes with spread greater than 30% of the mid price (of the bid and ask) are considered as not appropriate. The spread is computed as:

Spread = (Ask – Bid) / Average of Bid and Ask

Such of those strikes which are identified as not appropriate as mentioned above, or for which, no quotes are available in the order book, mid-quotes are computed using cubic spline, subject to other conditions explained below.

4.2.1. Cubic Spline Fitting

The table given below provides the mid price and spreads of various strikes of call and put options. It may be observed that in respect of four relevant strikes (three for puts and one for call), as highlighted, the quotes are not considered appropriate.

Strike	Call Bid (Rs.)	Call Ask (Rs.)	Call mid (Rs.)	Call spread	Put Bid (Rs.)	Put Ask (Rs.)	Put mid (Rs.)	Put spread
3800	1290.10	1314.25	1302.18	2%	0.40	0.50	0.45	22%
3900	1192.95	1212.80	1202.88	2%	0.35	0.80	0.58	78%
4000	1103.00	1107.95	1105.48	0%	0.70	0.85	0.78	19%
4100	1005.00	1017.10	1011.05	1%	0.80	1.10	0.95	32%
4200	894.95	913.90	904.43	2%	1.00	1.20	1.10	18%
4300	800.00	809.95	804.98	1%	1.20	1.70	1.45	34%
4400	696.15	709.50	702.83	2%	1.90	2.00	1.95	5%
4500	601.25	609.55	605.40	1%	3.30	3.45	3.38	4%
4600	500.70	520.00	510.35	4%	4.45	4.50	4.48	1%
4700	410.00	416.55	413.28	2%	7.70	8.00	7.85	4%
4800	316.00	321.05	318.53	2%	13.20	13.40	13.30	2%
4900	226.00	228.00	227.00	1%	22.50	22.65	22.58	1%
5000	144.50	145.00	144.75	0%	40.40	40.50	40.45	0%
5100	79.00	79.10	79.05	0%	74.40	74.50	74.45	0%
5200	34.75	35.00	34.88	1%	129.00	129.95	129.48	1%
5300	11.50	11.55	11.53	0%	200.55	206.00	203.28	3%
5400	3.60	3.65	3.63	1%	286.00	307.00	296.50	7%
5500	1.70	1.95	1.83	14%	340.00	396.00	368.00	15%
5600	1.00	1.35	1.18	30%	481.00	507.35	494.18	5%
5700	0.70	1.00	0.85	35%	577.35	606.65	592.00	5%

The mid price in respect of these strikes shall be computed using 'cubic spline'. The variation of option quotes against strikes is not linear. Therefore the quotes cannot be fitted using a simple linear interpolation. Hence, the option quotes can be fitted using a polynomial function like cubic spline. India VIX computation uses natural cubic spline for this purpose. This method considers the mid quotes of the other NIFTY option contracts and interpolates for the quotes which are not appropriate/available.

4.2.2. Selection of knot points

In the table given above for the near month, four strikes were identified and highlighted. In respect of these four strikes, as stated before, cubic spline shall be applied, wherever possible. For application of cubic spline, knot points are required on both the sides of the strike for which fitting is to be done. In such of those cases where the strike does not lie within the range of the knot points, cubic spline cannot be used. Strikes remaining after filtration (i.e. strikes which are available or appropriate) are known as knot points. It may be observed that in respect of the call options – the highlighted strike 5700 does not lie within the range of the knot points. Hence in this case cubic spline could not be used. In respect of all the other highlighted strikes, cubic spline shall be used.

4.2.3. Equations of Cubic spline and the relationships between the various terms

The general form of the cubic equation in term of coefficient of variable is given as:

$$S_j(x) = a_j(x - x_j)^3 + b_j(x - x_j)^2 + c_j(x - x_j) + d_j \quad \text{:: Equation (1)}$$

Where, $S_j(x)$ represents the fitted value, x_j is the lower limit of each sub-interval (a subinterval consists of two consecutive knot points) and a_j, b_j, c_j and d_j are the coefficients and constant in the equation. In the instant case, taking the example of the highlighted strike of the put option 3900 (x), if we apply the Equation (1), $S_j(x)$, i.e. the mid quote for the strike 3900, shall represent the fitted value of this strike, and x and x_j shall be 3900 and 3800 respectively

To solve Equation (1) and arrive at the fitted value, the following procedure is adopted:

The second derivative of Equation (1) is referred to as M_j. Proceeding further and using the properties of cubic spline, the following relationship shall be arrived:

$$a_j = \frac{M_{j+1} - M_j}{6h_j}; b_j = \frac{M_j}{2}; c_j = \frac{Q(K_{j+1}) - Q(K_j)}{h_j} - \frac{2h_jM_j + h_jM_{j+1}}{6}; d_j = Q(K_j)$$

$M_1 = M_n = 0$ and j = the number of the selected knot points (from 1 to n)

To solve for M_j, (j = 2 to n -1) the following equation and the concept of matrices are used:

$$h_{j-1}M_{j-1} + 2(h_{j-1} + h_j)M_j + h_jM_{j+1} = 6(B_j - B_{j-1}) \quad \text{:: Equation (2)}$$

and $h_j = x_{j+1} - x_j$ & $B_j = \dfrac{Q(K_{j+1}) - Q(K_j)}{h_j}$

It may be noted that for the limited purpose of this equation, $Q(K_j)$ represents the mid quote of the strike x_j , i.e. the mid quote of 3800 and $Q(K_{j+1})$, that of 4000, the two consecutive knot points. It may be further noted that currently the appropriate mid quote for 3900 is not available and being computed using cubic spline.

On ascertaining the value of M_j using the relationship mentioned above, the values of the terms a_j, b_j, c_j and d_j, are ascertained.

To start with, at each knot points, two values, h_j and B_j are computed using the following formula:

4.2.4. Computation of h_j and B_j

j	Strike Price x_j	Put Mid quote $Q(K_j)$	$h_j = x_{j+1} - x_j$	$B_j = \dfrac{Q(K_{j+1}) - Q(K_j)}{h_j}$
1	3800	0.45	200	0.001625
2	4000	0.78	200	0.001625
3	4200	1.10	200	0.004250
4	4400	1.95	100	0.014250
5	4500	3.38	100	0.011000
6	4600	4.48	100	0.033750
7	4700	7.85	100	0.054500
8	4800	13.30	100	0.092750
9	4900	22.58	100	0.178750
10	5000	40.45	100	0.340000
11	5100	74.45	100	0.550250
12	5200	129.48	100	0.738000
13	5300	203.28	100	0.932250
14	5400	296.50	100	0.715000
15	5500	368.00	100	1.261750
16	5600	494.18	100	0.978250
17	5700	592.00	-	-

4.2.5. Construction of Equation (2) for each knot

Splines are constructed by connecting the consecutive knot points using cubic equation. As stated above, the cubic equation can be expressed in terms of second derivative (M_j) using the generalized form given below and earlier referred to as Equation (2)

$h_{j-1}M_{j-1} + 2(h_{j-1} + h_j)M_j + h_jM_{j+1} = 6(B_j - B_{j-1})$ For knot point j = 2 to n-1

For various knots:

j	Strike Price x_j	$h_{j-1}M_{j-1} + 2(h_{j-1} + h_j)M_j + h_jM_{j+1}$	$6(B_j - B_{j-1})$
2	4000	$200M_1+800M_2+200M_3$	0.000000
3	4200	$200M_2+800M_3+200M_4$	0.015750
4	4400	$200M_3+600M_4+100M_5$	0.060000
5	4500	$100M_4+400M_5+100M_6$	-0.019500
6	4600	$1000M_5+400M_6+100M_7$	0.136500
7	4700	$100M_6+400M_7+100M_8$	0.124500
8	4800	$100M_7+400M_8+100M_9$	0.229500
9	4900	$100M_8+400M_9+100M_{10}$	0.516000
10	5000	$100M_9+400M_{10}+100M_{11}$	0.967500
11	5100	$100M_{10}+400M_{11}+100M_{12}$	1.261500
12	5200	$100M_{11}+400M_{12}+100M_{13}$	1.126500
13	5300	$100M_{12}+400M_{13}+100M_{14}$	1.165500
14	5400	$100M_{13}+400M_{14}+100M_{15}$	-1.303500
15	5500	$100M_{14}+400M_{15}+100M_{16}$	3.280500
16	5600	$100M_{15}+400M_{16}+100M_{17}$	-1.701000

4.2.6. Solving for M_j for each knot point using matrix algebra

Expressing the cubic equation of previous step in matrix form we get,

800	200	0	0	0	0	0	0	0	0	0	0	0	0	0	M2		0.000000
200	800	200	0	0	0	0	0	0	0	0	0	0	0	0	M3		0.015750
0	200	600	100	0	0	0	0	0	0	0	0	0	0	0	M4		0.060000
0	0	100	400	100	0	0	0	0	0	0	0	0	0	0	M5		-0.019500
0	0	0	100	400	100	0	0	0	0	0	0	0	0	0	M6		0.136500
0	0	0	0	100	400	100	0	0	0	0	0	0	0	0	M7		0.124500
0	0	0	0	0	100	400	100	0	0	0	0	0	0	0	M8	=	0.229500
0	0	0	0	0	0	100	400	100	0	0	0	0	0	0	M9		0.516000
0	0	0	0	0	0	0	100	400	100	0	0	0	0	0	M10		0.967500
0	0	0	0	0	0	0	0	100	400	100	0	0	0	0	M11		1.261500
0	0	0	0	0	0	0	0	0	100	400	100	0	0	0	M12		1.126500
0	0	0	0	0	0	0	0	0	0	100	400	100	0	0	M13		1.165500
0	0	0	0	0	0	0	0	0	0	0	100	400	100	0	M14		-1.303500
0	0	0	0	0	0	0	0	0	0	0	0	100	400	100	M15		3.280500
0	0	0	0	0	0	0	0	0	0	0	0	0	100	400	M16		-1.701000

On solving the matrix multiplication we get the array of variables M_j value for j = 2 to n-1

M2		0.000004
M3		-0.000014
M4		0.000133
M5		-0.000169
M6		0.000349
M7		0.000140
M8	=	0.000337
M9		0.000807
M10		0.001595
M11		0.002486
M12		0.001075
M13		0.004480
M14		-0.007338
M15		0.011839
M16		-0.007212

4.2.7. Computation of the co-efficients of variables of cubic equation

Using the relationship mentioned above and reiterated below, for j = 1 to n-1:

$$a_j = \frac{M_{j+1} - M_j}{6h_j}; b_j = \frac{M_j}{2}; c_j = \frac{Q(K_{j+1}) - Q(K_j)}{h_j} - \frac{2h_j M_j + h_j M_{j+1}}{6}; d_j = Q(K_j)$$

j	a_j	b_j	c_j	d_j
1	3.01E-09	0.000000	0.001504	0.450000
2	-1.51E-08	0.000002	0.001866	0.775000
3	1.23E-07	-0.000007	0.000781	1.100000
4	-0.000001	0.000067	0.012635	1.950000

5	0.000001	-0.000085	0.010829	3.375000
6	-3.48E-07	0.000174	0.019800	4.475000
7	3.29E-07	0.000070	0.044221	7.850000
8	0.000001	0.000169	0.068066	13.300000
9	0.000001	0.000403	0.125263	22.575000
10	0.000001	0.000798	0.245381	40.450000
11	-0.000002	0.001243	0.449464	74.450000
12	0.000006	0.000537	0.627513	129.475000
13	-0.000020	0.002240	0.905235	203.275000
14	0.000032	-0.003669	0.762298	296.500000
15	-0.000032	0.005919	0.987324	368.000000
16	0.000012	-0.003606	1.218658	494.175000

(It may be noted that some of the values which are very small are represented in terms of 'E')

4.2.8. Mid value of the highlighted strikes

The mid values of the highlighted strikes are now arrived at using the values ascertained above and substituting them in the Equation (1) as mentioned above and reiterated below:

$$S_j(x) = a_j(x - x_j)^3 + b_j(x - x_j)^2 + c_j(x - x_j) \ + d_j$$

We get the following cubic equations joining the relevant consecutive knot points,

x	Equation	Fitted value
3900	3.01E-09 (3900-3800)^3 + 0.00 (3900-3800)^2 + 0.001504(3900-3800) + 0.45	0.60
4100	-1.51E-08 (4100-4000)^3 + 0.000002(4100-4000)^2 + 0.001866(4100-4000) + 0.775	0.96
4300	1.23E-07 (4300-4200)^3 - 0.000007(4300-4200)^2 + 0.000781(4300-4200) + 1.1	1.23

Similarly, cubic spline is constructed separately for next month - both call and put contracts. Placed below is the order book snap shot of the next month. As may be observed below, in respect of none of the strikes, the spread is above 30% for both call and put contracts. Hence the cubic spline shall not be used for the purpose of fitting the mid quotes in respect of any strikes.

Strike	Call Bid	Call Ask	Call mid	Call spread	Put Bid	Put Ask	Put mid	Put spread
4000	1100.15	1110.00	1105.08	1%	5.90	6.50	6.20	10%
4100	1006.25	1026.90	1016.58	2%	7.15	8.50	7.83	17%
4200	905.15	931.15	918.15	3%	10.00	10.70	10.35	7%
4300	809.15	844.75	826.95	4%	13.55	14.00	13.78	3%
4400	713.10	732.85	722.98	3%	18.00	18.75	18.38	4%
4500	615.70	668.35	642.03	8%	22.35	25.00	23.68	11%
4600	526.80	572.05	549.43	8%	32.00	33.30	32.65	4%
4700	444.35	464.15	454.25	4%	41.00	45.00	43.00	9%
4800	366.60	408.60	387.60	11%	61.50	62.00	61.75	1%
4900	300.00	307.30	303.65	2%	84.55	86.50	85.53	2%
5000	231.00	232.00	231.50	0%	116.00	117.00	116.50	1%
5100	171.10	171.50	171.30	0%	156.00	158.00	157.00	1%
5200	120.05	121.80	120.93	1%	203.00	209.35	206.18	3%
5300	79.60	80.50	80.05	1%	252.85	265.00	258.93	5%
5400	48.10	48.50	48.30	1%	322.45	345.65	334.05	7%
5500	29.00	32.00	30.50	10%	405.00	437.10	421.05	8%
5600	15.90	19.85	17.88	22%	477.85	509.00	493.43	6%
5700	9.15	9.75	9.45	6%	575.25	609.00	592.13	6%

For the purposes of India VIX computation, the cubic spline shall be constructed only when the data set has at least 3 knot points from option contracts which are out-of the money or at the money. If the required number of knot points in near or next month is not available, then the spline construction process is not undertaken and volatility is not computed for the corresponding month.

5. Computation of Volatility

The relevant options strikes were identified and indicated above. The appropriate mid quotes (using the actual/ fitted ones, as the case may be) were ascertained as outlined above. The values in respect of the near month are reiterated as below:

Near Month Options			
Option Strike Price	**Mid Call Quote**	**Mid Put Quote**	**$Q(K_i)$**
3800		0.45	0.45
3900		0.6	0.6
4000		0.78	0.78
4100		0.96	0.96
4200		1.1	1.1
4300		1.23	1.23
4400		1.95	1.95
4500		3.38	3.38
4600		4.48	4.48
4700		7.85	7.85
4800		13.3	13.3
4900		22.58	22.58
5000		40.45	40.45
5100	79.05	74.45	76.75
5200	34.88		34.88
5300	11.53		11.53
5400	3.63		3.63
5500	1.83		1.83
5600	1.18		1.18

In respect of K_0 (ATM), it may be noted that both the put and call option contracts are considered and the average of the mid price of the quotes of both the call and put are taken. In respect of all the other strikes, either a put or a call is considered for the computation of India VIX. In the example above, the mid-quote used for the 5100 strike in the near term is therefore the average of the mid quotes of both the call and put, i.e., (79.05 + 74.45)/2 =76.75.

In respect of the next month, the values are:

Next Month Options			
Option Strike Price	**Mid Call Quote**	**Mid Put Quote**	**Q(K_i)**
4000		6.20	6.20
4100		7.83	7.83
4200		10.35	10.35
4300		13.78	13.78
4400		18.38	18.38
4500		23.68	23.68
4600		32.65	32.65
4700		43.00	43.00
4800		61.75	61.75
4900		85.53	85.53
5000		116.50	116.50
5100	171.30	157.00	164.15
5200	120.93		120.93
5300	80.05		80.05
5400	48.30		48.30
5500	30.50		30.50
5600	17.88		17.88
5700	9.45		9.45

The volatility for both near month and next month options are then calculated by applying the formula for calculating the India VIX with time to expiration of T_1 and T_2, respectively

$$\sigma_1^2 = \frac{2}{T_1}\sum \frac{\Delta K_i}{K_i^2} e^{R_1 T_1} Q(K_i) - \frac{1}{T_1}\left[\frac{F_1}{K_0} - 1\right]^2 \quad \text{- Equation (3)}$$

$$\sigma_2^2 = \frac{2}{T_2}\sum \frac{\Delta K_i}{K_i^2} e^{R_2 T_2} Q(K_i) - \frac{1}{T_2}\left[\frac{F_2}{K_0} - 1\right]^2 \quad \text{- Equation (4)}$$

The contribution of a single option to India VIX value is proportional to the quote of that option and inversely proportional to the option contract's strike price. For example, the contribution of the near month 3800 put contract is given by $\frac{\Delta K_{3800PUT}}{K_{3800PUT}^2} e^{R_1 T_1} Q(3800\text{ PUT})$

Generally, ΔK_i is half the distance between the strike on either side of K_i, but at the upper and lower edges of any given strip of options, ΔK_i is simply the difference between K_i and the adjacent strike price. In this case, 3800 is the lowest strike in the strip of near month options and 3900 happens to be the adjacent strike. Therefore, $\Delta K_{3800\ PUT}$ = 100 (i.e.3900 – 3800), and

$$\frac{\Delta K_{3800PUT}}{K_{3800PUT}^2} e^{R_1 T_1} Q(3800\ \text{PUT}) = \frac{100}{3800^2} * e^{(0.039*0.02466)} * (0.45) = 0.000003$$

The detailed computation in respect of each strike and the summation of the values are as under:

Option Strike Price	Option Type	Mid-quote	Contribution by strike $\frac{\Delta K_i}{K_i^2} e^{R_1 T_1} Q(K_i)$
3800	Put	0.45	0.000003
3900	Put	0.60	0.000004
4000	Put	0.78	0.000005
4100	Put	0.96	0.000006
4200	Put	1.10	0.000006
4300	Put	1.23	0.000007
4400	Put	1.95	0.000010
4500	Put	3.38	0.000017
4600	Put	4.48	0.000021
4700	Put	7.85	0.000036
4800	Put	13.30	0.000058
4900	Put	22.58	0.000094
5000	Put	40.45	0.000162
5100	Call/Put Average	76.75	0.000295
5200	Call	34.88	0.000129
5300	Call	11.53	0.000041
5400	Call	3.63	0.000012
5500	Call	1.83	0.000006
5600	Call	1.18	0.000004
$\sum \frac{\Delta K_i}{K_i^2} e^{R_1 T_1} Q(K_i)$			0.000916

This summation value for the near month options is multiplied by $2/T_1$ as given in the above Equation (3):

$$\sigma_1^2 = 0.000916*2/0.02466 - 1/0.02466*[(5129/5100)-1]^2 = 0.072979$$

Similarly we compute the volatility for next month,

Option Strike Price	Option Type	Mid-quote	Contribution by strike $\frac{\Delta K_i}{K_i^2} e^{R_2 T_2} Q(K_i)$
4000	Put	6.20	0.000039
4100	Put	7.83	0.000047
4200	Put	10.35	0.000059
4300	Put	13.78	0.000075
4400	Put	18.38	0.000095
4500	Put	23.68	0.000117
4600	Put	32.65	0.000155
4700	Put	43.00	0.000196
4800	Put	61.75	0.000269
4900	Put	85.53	0.000358
5000	Put	116.50	0.000468
5100	Call/Put Average	164.15	0.000634
5200	Call	120.93	0.000449
5300	Call	80.05	0.000286
5400	Call	48.30	0.000166
5500	Call	30.50	0.000101
5600	Call	17.88	0.000057
5700	Call	9.45	0.000029
		$\sum \frac{\Delta K_i}{K_i^2} e^{R_2 T_2} Q(K_i)$	0.003600

This summation value for the next month options is multiplied by $2/T_2$ as given in the above Equation (4):

$$\sigma_2^2 = 0.003600*2/0.10137 - 1/0.10137*[(5115/5100)-1]^2 = 0.070942$$

6. Computation of India VIX from the Volatilities

India VIX (σ*100) value is arrived at by interpolating the near and next month sigma (σ_1 and σ_2) values. If either of the month's sigma value is not computed then the previous tick's sigma value for the corresponding month is carried forward for computation. However, if India VIX is not computed at least once for the day then the previous India VIX value is carried forward.

σ_1 and σ_2 are interpolated to arrive at a single value with a constant maturity of 30 days to expiration. The formula used for interpolation is as under:

$$\sigma = \sqrt{\left\{T_1\sigma_1^2\left[\frac{N_{T_2} - N_{30}}{N_{T_2} - N_{T_1}}\right] + T_2\sigma_2^2\left[\frac{N_{30} - N_{T_1}}{N_{T_2} - N_{T_1}}\right]\right\} \times \frac{N_{365}}{N_{30}}}$$

Where,

NT_1 (number of minutes to expiration of the near month options) = 12960

NT_2 (number of minutes to expiration of the next month options) = 53280

N_{30} = (number of minutes in 30 days) =12960

N_{365} = (number of minutes in a 365-day year) = 525600

Using the above equation, σ = 0.2666 and India VIX = 100 * σ = 26.66