

Final Exam

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1.1 Download the historical prices for the ticker "SPY" from 2019-01-01 until now.

```
library(quantmod)

## Loading required package: xts

## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##   as.Date, as.Date.numeric

##
## ##### WARNING #####
## # We noticed you have dplyr installed. The dplyr lag() function breaks how
## # base R's lag() function is supposed to work, which breaks lag(my_xts).
## #
## # If you call library(dplyr) later in this session, then calls to lag(my_xts)
## # that you enter or source() into this session won't work correctly.
## #
## # All package code is unaffected because it is protected by the R namespace
## # mechanism.
## #
## # Set 'options(xts.warn_dplyr_breaks_lag = FALSE)' to suppress this warning.
## #
## # You can use stats::lag() to make sure you're not using dplyr::lag(), or you
## # can add conflictRules('dplyr', exclude = 'lag') to your .Rprofile to stop
## # dplyr from breaking base R's lag() function.
## ##### WARNING #####

## Loading required package: TTR

## Registered S3 method overwritten by 'quantmod':
##   method      from
##   as.zoo.data.frame zoo
```

```
getSymbols(Symbols = "SPY", from = '2019-01-01', to = '2023-05-02')
```

```
## [1] "SPY"
```

```
head(SPY)
```

```
##           SPY.Open SPY.High SPY.Low SPY.Close SPY.Volume SPY.Adjusted
## 2019-01-02    245.98   251.21  245.95    250.18  126925200    233.1717
## 2019-01-03    248.23   248.57  243.67    244.21  144140700    227.6076
## 2019-01-04    247.59   253.11  247.17    252.39  142628800    235.2315
## 2019-01-07    252.69   255.95  251.69    254.38  103139100    237.0862
## 2019-01-08    256.82   257.31  254.00    256.77  102512600    239.3137
## 2019-01-09    257.56   258.91  256.19    257.97   95006600    240.4321
```

```
tail(SPY)
```

```
##           SPY.Open SPY.High SPY.Low SPY.Close SPY.Volume SPY.Adjusted
## 2023-04-24    411.99   413.07  410.60    412.63   64332100    412.63
## 2023-04-25    410.58   411.16  406.02    406.08   97766700    406.08
## 2023-04-26    406.72   407.84  403.78    404.36   80447000    404.36
## 2023-04-27    407.00   412.69  406.74    412.41   92968400    412.41
## 2023-04-28    411.49   415.94  411.43    415.93   89335600    415.93
## 2023-05-01    415.47   417.62  415.27    415.51   62065200    415.51
```

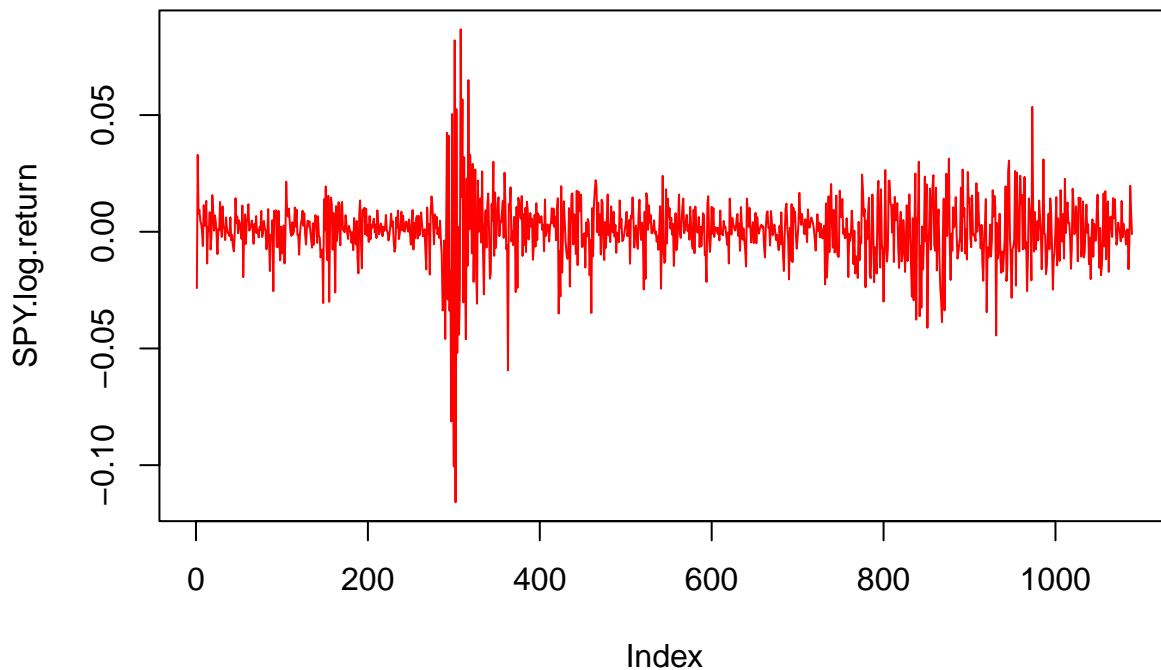
1.2 Calculate the daily log returns for SPY using the adjusted close prices.

```
SPY <- data.frame(SPY)
SPY.price <- SPY$SPY.Adjusted
SPY.log.price <- log(SPY.price)
SPY.log.return <- diff(SPY.log.price)
head(SPY.log.return)
```

```
## [1] -0.024152008  0.032947048  0.007853678  0.009351489  0.004662448
## [6]  0.003521503
```

1.3 Plot the daily log returns in red line.

```
plot(SPY.log.return, type = "l", col = "red")
```



2.1 Calculate the skewness and kurtosis of the SPY daily log return from Question 1, for both adjusted and unadjusted ones. (See page 21 and 23 of L6 and the corresponding HW problems)

```
skewness <- function(x, adjusted = FALSE){

  m3 <- mean((x - mean(x))^3)
  m2 <- mean((x - mean(x))^2)
  m_tilde_3 <- m3/m2^(3/2)
  if(adjusted == F){

    return(paste("Unadjusted Skewness: ", m_tilde_3))
  }
  else {

    n <- length(x)
    m_tilde_3_adjusted <- (sqrt(n*(n-1))/(n-2))*m_tilde_3
    return(paste("Adjusted Skewness: ", m_tilde_3_adjusted))
  }
}
skewness(SPY.log.return, adjusted = T)
```

```
## [1] "Adjusted Skewness: -0.805513602825177"
```

```
skewness(SPY.log.return, adjusted = F)
```

```
## [1] "Unadjusted Skewness: -0.804403655164189"
```

```
kurtosis <- function(x, adjusted = FALSE){

  m2 <- mean((x - mean(x))^2)
  m4 <- mean((x - mean(x))^4)
  m_tilde_4 <- m4/m2^(4/2)
  if(adjusted == F){

    return(paste("Unadjusted kurtosis: ", m_tilde_4))
  }
  else{

    n <- length(x)
    m_tilde_4_adjusted <- ((n-1)/((n-2)*(n-3)))*((n+1)*m_tilde_4-3*(n-1))+3
    return(paste("Adjusted kurtosis: ", m_tilde_4_adjusted))
  }
}

kurtosis(SPY.log.return, adjusted = T)
```

```
## [1] "Adjusted kurtosis: 14.4727670607345"
```

```
kurtosis(SPY.log.return, adjusted = F)
```

```
## [1] "Unadjusted kurtosis: 14.4146544500388"
```

2.2 Report the results in 2.1 using a 2×2 table (either data frame or matrix) such that: The column names are "SPY.skewness" and "SPY.kurtosis". And the row names are "Unadjusted" and "Adjusted".

```
x <- data.frame (SPY.skewness = c (skewness(SPY.log.return, adjusted = T), skewness(SPY.log.return, adjusted = F)),
rownames(x) <- c("Adjusted", "Unadjusted"))
x
```

```
##                               SPY.skewness
## Adjusted      Adjusted Skewness: -0.805513602825177
## Unadjusted Unadjusted Skewness: -0.804403655164189
##                               SPY.kurtosis
## Adjusted      Adjusted kurtosis: 14.4727670607345
## Unadjusted Unadjusted kurtosis: 14.4146544500388
```

3.1 Download options prices for ticker "SPY" for all expiration dates.

```
library(quantmod)
SPY.option<- getOptionChain("SPY")
head(SPY.option)
```

```
## $calls
##      ContractID ContractSize Currency Expiration Strike   Last      Chg
## 1  SPY230502C00300000    REGULAR      USD 2023-05-02   300 115.85  0.00000000
## 2  SPY230502C00310000    REGULAR      USD 2023-05-02   310 101.10 -1.81000520
## 3  SPY230502C00350000    REGULAR      USD 2023-05-02   350  57.19  0.00000000
## 4  SPY230502C00352000    REGULAR      USD 2023-05-02   352  62.00  0.00000000
```

## 5	SPY230502C00360000	REGULAR	USD	2023-05-02	360	55.16	0.00000000
## 6	SPY230502C00368000	REGULAR	USD	2023-05-02	368	48.18	0.00000000
## 7	SPY230502C00375000	REGULAR	USD	2023-05-02	375	33.87	-7.04999900
## 8	SPY230502C00380000	REGULAR	USD	2023-05-02	380	30.15	-5.58000000
## 9	SPY230502C00385000	REGULAR	USD	2023-05-02	385	30.64	0.00000000
## 10	SPY230502C00386000	REGULAR	USD	2023-05-02	386	21.36	0.00000000
## 11	SPY230502C00388000	REGULAR	USD	2023-05-02	388	22.27	-7.04999900
## 12	SPY230502C00389000	REGULAR	USD	2023-05-02	389	21.02	-6.27999900
## 13	SPY230502C00390000	REGULAR	USD	2023-05-02	390	20.38	-6.44000050
## 14	SPY230502C00392000	REGULAR	USD	2023-05-02	392	16.78	-8.00000000
## 15	SPY230502C00393000	REGULAR	USD	2023-05-02	393	21.16	-1.76000020
## 16	SPY230502C00394000	REGULAR	USD	2023-05-02	394	21.19	0.00000000
## 17	SPY230502C00395000	REGULAR	USD	2023-05-02	395	15.27	-5.86999900
## 18	SPY230502C00396000	REGULAR	USD	2023-05-02	396	12.53	-5.97000030
## 19	SPY230502C00397000	REGULAR	USD	2023-05-02	397	13.67	1.85999970
## 20	SPY230502C00398000	REGULAR	USD	2023-05-02	398	17.65	0.00000000
## 21	SPY230502C00399000	REGULAR	USD	2023-05-02	399	10.50	-6.50000000
## 22	SPY230502C00400000	REGULAR	USD	2023-05-02	400	10.50	-5.59000000
## 23	SPY230502C00401000	REGULAR	USD	2023-05-02	401	9.39	-5.06999970
## 24	SPY230502C00402000	REGULAR	USD	2023-05-02	402	7.93	-5.67000060
## 25	SPY230502C00403000	REGULAR	USD	2023-05-02	403	7.30	-5.67999940
## 26	SPY230502C00404000	REGULAR	USD	2023-05-02	404	6.50	-5.41000000
## 27	SPY230502C00405000	REGULAR	USD	2023-05-02	405	5.51	-5.17000000
## 28	SPY230502C00406000	REGULAR	USD	2023-05-02	406	4.40	-5.35000000
## 29	SPY230502C00407000	REGULAR	USD	2023-05-02	407	3.55	-5.17999940
## 30	SPY230502C00408000	REGULAR	USD	2023-05-02	408	2.59	-5.10000040
## 31	SPY230502C00409000	REGULAR	USD	2023-05-02	409	1.71	-5.24000000
## 32	SPY230502C00410000	REGULAR	USD	2023-05-02	410	0.98	-4.97000000
## 33	SPY230502C00411000	REGULAR	USD	2023-05-02	411	0.46	-4.25999980
## 34	SPY230502C00412000	REGULAR	USD	2023-05-02	412	0.16	-3.61000000
## 35	SPY230502C00413000	REGULAR	USD	2023-05-02	413	0.05	-2.82000000
## 36	SPY230502C00414000	REGULAR	USD	2023-05-02	414	0.02	-1.98000000
## 37	SPY230502C00415000	REGULAR	USD	2023-05-02	415	0.01	-1.31000010
## 38	SPY230502C00416000	REGULAR	USD	2023-05-02	416	0.01	-0.76000000
## 39	SPY230502C00417000	REGULAR	USD	2023-05-02	417	0.01	-0.39000002
## 40	SPY230502C00418000	REGULAR	USD	2023-05-02	418	0.01	-0.17000000
## 41	SPY230502C00419000	REGULAR	USD	2023-05-02	419	0.01	-0.08000001
## 42	SPY230502C00420000	REGULAR	USD	2023-05-02	420	0.01	-0.04000000
## 43	SPY230502C00421000	REGULAR	USD	2023-05-02	421	0.01	-0.02000000
## 44	SPY230502C00422000	REGULAR	USD	2023-05-02	422	0.01	0.00000000
## 45	SPY230502C00423000	REGULAR	USD	2023-05-02	423	0.01	0.00000000
## 46	SPY230502C00424000	REGULAR	USD	2023-05-02	424	0.01	0.00000000
## 47	SPY230502C00425000	REGULAR	USD	2023-05-02	425	0.01	0.00000000
## 48	SPY230502C00426000	REGULAR	USD	2023-05-02	426	0.01	0.00000000
## 49	SPY230502C00427000	REGULAR	USD	2023-05-02	427	0.01	0.00000000
## 50	SPY230502C00428000	REGULAR	USD	2023-05-02	428	0.01	0.00000000
## 51	SPY230502C00429000	REGULAR	USD	2023-05-02	429	0.01	0.00000000
## 52	SPY230502C00430000	REGULAR	USD	2023-05-02	430	0.01	0.00000000
## 53	SPY230502C00431000	REGULAR	USD	2023-05-02	431	0.01	0.00000000
## 54	SPY230502C00432000	REGULAR	USD	2023-05-02	432	0.01	0.00000000
## 55	SPY230502C00433000	REGULAR	USD	2023-05-02	433	0.01	0.00000000
## 56	SPY230502C00434000	REGULAR	USD	2023-05-02	434	0.01	0.00000000
## 57	SPY230502C00435000	REGULAR	USD	2023-05-02	435	0.01	0.00000000
## 58	SPY230502C00436000	REGULAR	USD	2023-05-02	436	0.01	-0.01000000

## 59	SPY230502C00437000	REGULAR	USD	2023-05-02	437	0.01	0.00000000	
## 60	SPY230502C00438000	REGULAR	USD	2023-05-02	438	0.01	0.00000000	
## 61	SPY230502C00440000	REGULAR	USD	2023-05-02	440	0.01	0.00000000	
## 62	SPY230502C00441000	REGULAR	USD	2023-05-02	441	0.01	0.00000000	
## 63	SPY230502C00442000	REGULAR	USD	2023-05-02	442	0.01	0.00000000	
## 64	SPY230502C00450000	REGULAR	USD	2023-05-02	450	0.01	0.00000000	
## 65	SPY230502C00458000	REGULAR	USD	2023-05-02	458	0.01	0.00000000	
## 66	SPY230502C00470000	REGULAR	USD	2023-05-02	470	0.01	0.00000000	
##	ChgPct	Bid	Ask	Vol	OI	LastTradeTime	IV	ITM
## 1	0.000000	110.45	110.62	1	2	2023-05-01 09:37:28	0.00001000	TRUE
## 2	-1.758823	100.38	100.54	1	1	2023-05-02 10:23:38	0.00001000	TRUE
## 3	0.000000	60.40	60.58	1	1	2023-04-26 09:49:30	0.00001000	TRUE
## 4	0.000000	58.42	58.60	3	0	2023-04-28 11:30:24	0.00001000	TRUE
## 5	0.000000	50.42	50.60	3	3	2023-04-28 13:03:56	0.00001000	TRUE
## 6	0.000000	42.46	42.63	1	1	2023-05-01 09:43:28	0.00001000	TRUE
## 7	-17.228739	35.42	35.58	1	5	2023-05-02 11:12:32	0.00001000	TRUE
## 8	-15.617128	30.42	30.59	24	20	2023-05-02 13:32:47	0.00001000	TRUE
## 9	0.000000	25.41	25.59	5	7	2023-05-01 15:44:16	0.00001000	TRUE
## 10	0.000000	24.43	24.59	1	2	2023-04-27 09:38:13	0.00001000	TRUE
## 11	-24.045020	22.41	22.59	3	6	2023-05-02 13:35:22	0.00001000	TRUE
## 12	-23.003658	21.41	21.59	17	23	2023-05-02 10:47:24	0.00001000	TRUE
## 13	-24.011934	20.46	20.64	118	8264	2023-05-02 13:31:30	0.00001000	TRUE
## 14	-32.284100	18.44	18.62	11	16	2023-05-02 11:06:13	0.00001000	TRUE
## 15	-7.678884	17.44	17.62	6	12	2023-05-01 16:01:25	0.00001000	TRUE
## 16	0.000000	16.44	16.62	6	10	2023-04-28 15:28:13	0.00001000	TRUE
## 17	-27.767262	15.39	15.61	11	25	2023-05-02 13:28:09	0.00001000	TRUE
## 18	-32.270270	14.45	14.61	8	7	2023-05-02 11:52:00	0.00001000	TRUE
## 19	15.749362	13.40	13.59	1	5	2023-05-02 10:31:03	0.00001000	TRUE
## 20	0.000000	12.45	12.62	3	60	2023-05-01 15:44:35	0.00001000	TRUE
## 21	-38.235294	11.45	11.57	51	246	2023-05-02 12:40:31	0.00001000	TRUE
## 22	-34.742077	10.48	10.59	175	16930	2023-05-02 13:39:25	0.00001000	TRUE
## 23	-35.062237	9.48	9.59	11	393	2023-05-02 13:38:16	0.00001000	TRUE
## 24	-41.691180	8.48	8.62	490	740	2023-05-02 13:18:07	0.00001000	TRUE
## 25	-43.759630	7.46	7.60	374	1050	2023-05-02 13:29:31	0.00001000	TRUE
## 26	-45.424015	6.45	6.59	4315	1108	2023-05-02 13:39:18	0.00001000	TRUE
## 27	-48.408237	5.43	5.57	1795	1317	2023-05-02 13:39:18	0.00001000	TRUE
## 28	-54.871796	4.49	4.63	4197	2416	2023-05-02 13:35:31	0.00001000	TRUE
## 29	-59.335620	3.50	3.63	5718	2686	2023-05-02 13:41:53	0.00001000	TRUE
## 30	-66.319900	2.55	2.64	65862	2901	2023-05-02 13:41:39	0.00001000	TRUE
## 31	-75.395676	1.70	1.74	202203	3766	2023-05-02 13:41:52	0.00001000	TRUE
## 32	-83.529410	0.96	0.97	355938	11771	2023-05-02 13:41:48	0.04395487	TRUE
## 33	-90.254234	0.45	0.46	191062	4069	2023-05-02 13:41:54	0.06031213	FALSE
## 34	-95.755970	0.16	0.17	273489	6847	2023-05-02 13:41:53	0.06519490	FALSE
## 35	-98.257840	0.05	0.06	178096	3212	2023-05-02 13:41:38	0.07129835	FALSE
## 36	-99.000000	0.02	0.03	189610	4300	2023-05-02 13:41:40	0.08301698	FALSE
## 37	-99.242424	0.01	0.02	190495	26920	2023-05-02 13:40:52	0.09766527	FALSE
## 38	-98.701300	0.01	0.02	85700	18390	2023-05-02 13:41:47	0.11719633	FALSE
## 39	-97.500000	0.01	0.02	37159	32184	2023-05-02 13:41:10	0.13477428	FALSE
## 40	-94.444440	0.00	0.01	24494	17541	2023-05-02 13:38:04	0.14063359	FALSE
## 41	-88.888890	0.00	0.01	16265	14226	2023-05-02 13:38:10	0.15625844	FALSE
## 42	-79.999990	0.00	0.01	18363	22526	2023-05-02 13:39:07	0.17188328	FALSE
## 43	-66.666670	0.00	0.01	8209	9082	2023-05-02 13:31:43	0.19141434	FALSE
## 44	0.000000	0.00	0.01	583	6489	2023-05-02 12:54:59	0.20703918	FALSE
## 45	0.000000	0.00	0.01	1090	4857	2023-05-02 13:23:09	0.22266402	FALSE

##	46	0.000000	0.00	0.01	468	6330	2023-05-02	12:30:04	0.23828887	FALSE
##	47	0.000000	0.00	0.01	83	3813	2023-05-02	11:38:23	0.25391371	FALSE
##	48	0.000000	0.00	0.01	77	3938	2023-05-02	12:00:21	0.26953855	FALSE
##	49	0.000000	0.00	0.01	32	684	2023-05-02	12:01:13	0.28516340	FALSE
##	50	0.000000	0.00	0.01	2	1164	2023-05-02	13:17:04	0.30078824	FALSE
##	51	0.000000	0.00	0.01	10	661	2023-05-02	13:18:04	0.31641309	FALSE
##	52	0.000000	0.00	0.01	69	823	2023-05-02	11:03:02	0.32813172	FALSE
##	53	0.000000	0.00	0.01	1	13	2023-05-02	11:03:02	0.34375656	FALSE
##	54	0.000000	0.00	0.01	2	55	2023-05-02	10:47:13	0.35938141	FALSE
##	55	0.000000	0.00	0.01	2	104	2023-05-02	10:32:19	0.37500625	FALSE
##	56	0.000000	0.00	0.01	1	274	2023-05-02	09:37:01	0.39063109	FALSE
##	57	0.000000	0.00	0.01	3	105	2023-05-02	10:15:32	0.40625594	FALSE
##	58	-50.000000	0.00	0.01	2	40	2023-05-02	09:31:42	0.42188078	FALSE
##	59	0.000000	0.00	0.01	11	1	2023-05-02	13:19:47	0.43750563	FALSE
##	60	0.000000	0.00	0.01	1	3	2023-05-01	15:51:52	0.45313047	FALSE
##	61	0.000000	0.00	0.01	23	73	2023-04-24	15:17:05	0.47656773	FALSE
##	62	0.000000	0.00	0.01	1	1	2023-04-28	10:34:30	0.49219258	FALSE
##	63	0.000000	0.00	0.01	1	8	2023-05-02	10:27:18	0.50781742	FALSE
##	64	0.000000	0.00	0.01	NA	6	2023-04-19	09:30:06	0.57812922	FALSE
##	65	0.000000	0.00	0.01	2	2	2023-05-02	09:46:53	0.68750313	FALSE
##	66	0.000000	0.00	0.01	1	2	2023-04-28	09:30:09	0.82812672	FALSE

##

\$puts

##	ContractID	ContractSize	Currency	Expiration	Strike	Last	Chg
##	1	SPY230502P00270000	REGULAR	USD	2023-05-02	270	0.01 0.000000
##	2	SPY230502P00280000	REGULAR	USD	2023-05-02	280	0.01 0.000000
##	3	SPY230502P00290000	REGULAR	USD	2023-05-02	290	0.01 0.000000
##	4	SPY230502P00300000	REGULAR	USD	2023-05-02	300	0.01 0.000000
##	5	SPY230502P00310000	REGULAR	USD	2023-05-02	310	0.01 0.000000
##	6	SPY230502P00320000	REGULAR	USD	2023-05-02	320	0.01 0.000000
##	7	SPY230502P00330000	REGULAR	USD	2023-05-02	330	0.01 0.000000
##	8	SPY230502P00340000	REGULAR	USD	2023-05-02	340	0.03 0.000000
##	9	SPY230502P00345000	REGULAR	USD	2023-05-02	345	0.01 0.000000
##	10	SPY230502P00346000	REGULAR	USD	2023-05-02	346	0.01 0.000000
##	11	SPY230502P00347000	REGULAR	USD	2023-05-02	347	0.01 0.000000
##	12	SPY230502P00348000	REGULAR	USD	2023-05-02	348	0.01 0.000000
##	13	SPY230502P00349000	REGULAR	USD	2023-05-02	349	0.01 0.000000
##	14	SPY230502P00350000	REGULAR	USD	2023-05-02	350	0.01 0.000000
##	15	SPY230502P00351000	REGULAR	USD	2023-05-02	351	0.01 0.000000
##	16	SPY230502P00352000	REGULAR	USD	2023-05-02	352	0.01 0.000000
##	17	SPY230502P00353000	REGULAR	USD	2023-05-02	353	0.01 0.000000
##	18	SPY230502P00354000	REGULAR	USD	2023-05-02	354	0.01 0.000000
##	19	SPY230502P00355000	REGULAR	USD	2023-05-02	355	0.01 0.000000
##	20	SPY230502P00356000	REGULAR	USD	2023-05-02	356	0.02 0.000000
##	21	SPY230502P00357000	REGULAR	USD	2023-05-02	357	0.02 0.000000
##	22	SPY230502P00358000	REGULAR	USD	2023-05-02	358	0.01 -0.010000
##	23	SPY230502P00359000	REGULAR	USD	2023-05-02	359	0.03 0.000000
##	24	SPY230502P00360000	REGULAR	USD	2023-05-02	360	0.01 -0.020000
##	25	SPY230502P00361000	REGULAR	USD	2023-05-02	361	0.03 0.000000
##	26	SPY230502P00362000	REGULAR	USD	2023-05-02	362	0.02 0.000000
##	27	SPY230502P00363000	REGULAR	USD	2023-05-02	363	0.03 0.000000
##	28	SPY230502P00364000	REGULAR	USD	2023-05-02	364	0.02 0.000000
##	29	SPY230502P00365000	REGULAR	USD	2023-05-02	365	0.03 0.000000
##	30	SPY230502P00366000	REGULAR	USD	2023-05-02	366	0.01 0.000000

## 31	SPY230502P00367000	REGULAR	USD	2023-05-02	367	0.03	0.000000
## 32	SPY230502P00368000	REGULAR	USD	2023-05-02	368	0.06	0.000000
## 33	SPY230502P00369000	REGULAR	USD	2023-05-02	369	0.03	0.000000
## 34	SPY230502P00370000	REGULAR	USD	2023-05-02	370	0.01	0.000000
## 35	SPY230502P00371000	REGULAR	USD	2023-05-02	371	0.02	0.000000
## 36	SPY230502P00372000	REGULAR	USD	2023-05-02	372	0.02	0.000000
## 37	SPY230502P00373000	REGULAR	USD	2023-05-02	373	0.02	0.000000
## 38	SPY230502P00374000	REGULAR	USD	2023-05-02	374	0.02	0.000000
## 39	SPY230502P00375000	REGULAR	USD	2023-05-02	375	0.02	0.000000
## 40	SPY230502P00376000	REGULAR	USD	2023-05-02	376	0.02	0.000000
## 41	SPY230502P00377000	REGULAR	USD	2023-05-02	377	0.04	0.000000
## 42	SPY230502P00378000	REGULAR	USD	2023-05-02	378	0.03	0.000000
## 43	SPY230502P00379000	REGULAR	USD	2023-05-02	379	0.02	0.000000
## 44	SPY230502P00380000	REGULAR	USD	2023-05-02	380	0.01	0.000000
## 45	SPY230502P00381000	REGULAR	USD	2023-05-02	381	0.02	0.000000
## 46	SPY230502P00382000	REGULAR	USD	2023-05-02	382	0.01	0.000000
## 47	SPY230502P00383000	REGULAR	USD	2023-05-02	383	0.01	0.000000
## 48	SPY230502P00384000	REGULAR	USD	2023-05-02	384	0.01	0.000000
## 49	SPY230502P00385000	REGULAR	USD	2023-05-02	385	0.01	0.000000
## 50	SPY230502P00386000	REGULAR	USD	2023-05-02	386	0.01	0.000000
## 51	SPY230502P00387000	REGULAR	USD	2023-05-02	387	0.01	0.000000
## 52	SPY230502P00388000	REGULAR	USD	2023-05-02	388	0.01	0.000000
## 53	SPY230502P00389000	REGULAR	USD	2023-05-02	389	0.01	-0.010000
## 54	SPY230502P00390000	REGULAR	USD	2023-05-02	390	0.01	-0.010000
## 55	SPY230502P00391000	REGULAR	USD	2023-05-02	391	0.01	0.000000
## 56	SPY230502P00392000	REGULAR	USD	2023-05-02	392	0.01	-0.010000
## 57	SPY230502P00393000	REGULAR	USD	2023-05-02	393	0.01	0.000000
## 58	SPY230502P00394000	REGULAR	USD	2023-05-02	394	0.01	0.000000
## 59	SPY230502P00395000	REGULAR	USD	2023-05-02	395	0.01	0.000000
## 60	SPY230502P00396000	REGULAR	USD	2023-05-02	396	0.01	0.000000
## 61	SPY230502P00397000	REGULAR	USD	2023-05-02	397	0.01	-0.010000
## 62	SPY230502P00398000	REGULAR	USD	2023-05-02	398	0.01	0.000000
## 63	SPY230502P00399000	REGULAR	USD	2023-05-02	399	0.01	0.000000
## 64	SPY230502P00400000	REGULAR	USD	2023-05-02	400	0.01	-0.010000
## 65	SPY230502P00401000	REGULAR	USD	2023-05-02	401	0.01	0.000000
## 66	SPY230502P00402000	REGULAR	USD	2023-05-02	402	0.01	-0.010000
## 67	SPY230502P00403000	REGULAR	USD	2023-05-02	403	0.01	-0.010000
## 68	SPY230502P00404000	REGULAR	USD	2023-05-02	404	0.02	0.000000
## 69	SPY230502P00405000	REGULAR	USD	2023-05-02	405	0.02	-0.010000
## 70	SPY230502P00406000	REGULAR	USD	2023-05-02	406	0.03	0.000000
## 71	SPY230502P00407000	REGULAR	USD	2023-05-02	407	0.06	0.030000
## 72	SPY230502P00408000	REGULAR	USD	2023-05-02	408	0.10	0.070000
## 73	SPY230502P00409000	REGULAR	USD	2023-05-02	409	0.20	0.160000
## 74	SPY230502P00410000	REGULAR	USD	2023-05-02	410	0.47	0.410000
## 75	SPY230502P00411000	REGULAR	USD	2023-05-02	411	0.96	0.880000
## 76	SPY230502P00412000	REGULAR	USD	2023-05-02	412	1.68	1.550000
## 77	SPY230502P00413000	REGULAR	USD	2023-05-02	413	2.51	2.290000
## 78	SPY230502P00414000	REGULAR	USD	2023-05-02	414	3.53	3.130000
## 79	SPY230502P00415000	REGULAR	USD	2023-05-02	415	4.43	3.750000
## 80	SPY230502P00416000	REGULAR	USD	2023-05-02	416	5.67	4.550000
## 81	SPY230502P00417000	REGULAR	USD	2023-05-02	417	6.55	4.790000
## 82	SPY230502P00418000	REGULAR	USD	2023-05-02	418	7.63	5.130000
## 83	SPY230502P00419000	REGULAR	USD	2023-05-02	419	8.49	5.019999
## 84	SPY230502P00420000	REGULAR	USD	2023-05-02	420	9.67	5.230000

## 85	SPY230502P00421000	REGULAR	USD	2023-05-02	421	11.54	6.090000	
## 86	SPY230502P00422000	REGULAR	USD	2023-05-02	422	12.07	5.790000	
## 87	SPY230502P00423000	REGULAR	USD	2023-05-02	423	13.55	6.170000	
## 88	SPY230502P00424000	REGULAR	USD	2023-05-02	424	15.00	6.750000	
## 89	SPY230502P00425000	REGULAR	USD	2023-05-02	425	16.26	7.100000	
## 90	SPY230502P00426000	REGULAR	USD	2023-05-02	426	16.55	6.339999	
## 91	SPY230502P00427000	REGULAR	USD	2023-05-02	427	11.16	0.000000	
## 92	SPY230502P00428000	REGULAR	USD	2023-05-02	428	19.05	6.719999	
## 93	SPY230502P00430000	REGULAR	USD	2023-05-02	430	20.00	5.950000	
## 94	SPY230502P00431000	REGULAR	USD	2023-05-02	431	18.82	3.820000	
##	ChgPct	Bid	Ask	Vol	OI	LastTradeTime	IV	ITM
## 1	0.00000	0.00	0.01	1	1	2023-04-28 10:12:02	2.43750391	FALSE
## 2	0.00000	0.00	0.01	1	1	2023-04-28 16:04:47	2.25000437	FALSE
## 3	0.00000	0.00	0.01	NA	103	2023-04-20 10:52:45	2.00000500	FALSE
## 4	0.00000	0.00	0.01	1	12	2023-05-02 09:49:31	1.84375078	FALSE
## 5	0.00000	0.00	0.01	1	220	2023-05-02 10:04:47	1.65625172	FALSE
## 6	0.00000	0.00	0.01	2	102	2023-04-26 10:43:34	1.50000250	FALSE
## 7	0.00000	0.00	0.01	5	11	2023-04-28 15:39:14	1.31250344	FALSE
## 8	0.00000	0.00	0.01	2	25	2023-04-25 13:54:43	1.15625422	FALSE
## 9	0.00000	0.00	0.01	261	255	2023-04-28 15:39:14	1.06250469	FALSE
## 10	0.00000	0.00	0.01	201	201	2023-04-28 15:33:32	1.06250469	FALSE
## 11	0.00000	0.00	0.01	300	300	2023-04-28 14:25:03	1.03125484	FALSE
## 12	0.00000	0.00	0.01	20	21	2023-04-28 15:23:23	1.00000500	FALSE
## 13	0.00000	0.00	0.01	300	300	2023-04-28 15:21:56	1.00000500	FALSE
## 14	0.00000	0.00	0.01	23	183	2023-04-28 09:49:35	0.96875031	FALSE
## 15	0.00000	0.00	0.01	28	48	2023-04-28 14:08:32	0.96875031	FALSE
## 16	0.00000	0.00	0.01	277	315	2023-04-28 16:12:03	0.93750062	FALSE
## 17	0.00000	0.00	0.01	301	301	2023-04-28 15:42:37	0.93750062	FALSE
## 18	0.00000	0.00	0.01	76	112	2023-04-28 16:07:43	0.90625094	FALSE
## 19	0.00000	0.00	0.01	554	596	2023-04-28 16:10:43	0.90625094	FALSE
## 20	0.00000	0.00	0.01	NA	50	2023-04-27 15:03:17	0.87500125	FALSE
## 21	0.00000	0.00	0.01	10	11	2023-04-26 12:09:50	0.87500125	FALSE
## 22	-50.00000	0.00	0.00	2	4	2023-04-27 10:15:35	0.50000500	FALSE
## 23	0.00000	0.00	0.01	2	10	2023-04-26 14:59:40	0.84375156	FALSE
## 24	-66.66667	0.00	0.01	7	86	2023-05-02 09:30:37	0.81250187	FALSE
## 25	0.00000	0.00	0.01	5	140	2023-04-27 12:56:35	0.81250187	FALSE
## 26	0.00000	0.00	0.01	NA	11	2023-04-27 11:38:51	0.78125219	FALSE
## 27	0.00000	0.00	0.01	5	7	2023-04-27 09:38:07	0.78125219	FALSE
## 28	0.00000	0.00	0.01	1	15	2023-04-28 14:33:28	0.75000250	FALSE
## 29	0.00000	0.00	0.01	1	22	2023-04-28 14:24:50	0.75000250	FALSE
## 30	0.00000	0.00	0.01	2	2	2023-04-28 16:03:16	0.71875281	FALSE
## 31	0.00000	0.00	0.01	7	11	2023-04-27 14:18:12	0.71875281	FALSE
## 32	0.00000	0.00	0.01	22	25	2023-04-25 14:58:58	0.68750313	FALSE
## 33	0.00000	0.00	0.01	68	106	2023-04-27 15:48:46	0.68750313	FALSE
## 34	0.00000	0.00	0.01	2	220	2023-04-28 15:37:51	0.65625344	FALSE
## 35	0.00000	0.00	0.01	170	170	2023-04-28 13:29:14	0.65625344	FALSE
## 36	0.00000	0.00	0.01	360	353	2023-04-28 15:29:09	0.62500375	FALSE
## 37	0.00000	0.00	0.01	35	53	2023-04-28 15:55:18	0.62500375	FALSE
## 38	0.00000	0.00	0.01	12	42	2023-04-28 16:08:17	0.59375406	FALSE
## 39	0.00000	0.00	0.01	7	182	2023-04-28 16:03:23	0.59375406	FALSE
## 40	0.00000	0.00	0.01	1	61	2023-04-28 16:02:45	0.56250438	FALSE
## 41	0.00000	0.00	0.01	36	308	2023-04-27 15:22:51	0.56250438	FALSE
## 42	0.00000	0.00	0.01	205	299	2023-04-27 16:01:24	0.53125469	FALSE
## 43	0.00000	0.00	0.01	2	286	2023-04-28 12:18:02	0.53125469	FALSE

## 44	0.00000	0.00	0.01	1	7115	2023-05-01	15:54:17	0.50000500	FALSE
## 45	0.00000	0.00	0.01	1	223	2023-04-28	14:09:08	0.50000500	FALSE
## 46	0.00000	0.00	0.01	24	107	2023-05-01	12:32:08	0.50781742	FALSE
## 47	0.00000	0.00	0.01	1	446	2023-05-02	10:15:36	0.49219258	FALSE
## 48	0.00000	0.00	0.01	165	231	2023-05-01	16:05:11	0.47656773	FALSE
## 49	0.00000	0.00	0.01	1	3924	2023-05-02	10:30:58	0.46094289	FALSE
## 50	0.00000	0.00	0.01	466	3065	2023-05-01	15:57:12	0.44531805	FALSE
## 51	0.00000	0.00	0.01	3	1612	2023-05-02	10:56:35	0.42969320	FALSE
## 52	0.00000	0.00	0.01	15	21177	2023-05-01	16:10:17	0.40625594	FALSE
## 53	-50.00000	0.00	0.01	45	4851	2023-05-02	11:25:14	0.39063109	FALSE
## 54	-50.00000	0.00	0.01	10	1211	2023-05-02	10:32:47	0.37500625	FALSE
## 55	0.00000	0.00	0.01	22	2418	2023-05-02	11:00:44	0.35938141	FALSE
## 56	-50.00000	0.00	0.01	12	3778	2023-05-02	11:21:57	0.34375656	FALSE
## 57	0.00000	0.00	0.01	30	1218	2023-05-02	12:18:47	0.32813172	FALSE
## 58	0.00000	0.00	0.01	160	1373	2023-05-02	11:52:00	0.31250687	FALSE
## 59	0.00000	0.00	0.01	1443	1817	2023-05-02	12:31:42	0.29297582	FALSE
## 60	0.00000	0.00	0.01	359	1154	2023-05-02	13:01:08	0.27344477	FALSE
## 61	-50.00000	0.00	0.01	4773	1289	2023-05-02	13:24:46	0.25781992	FALSE
## 62	0.00000	0.00	0.01	2640	3042	2023-05-02	13:25:01	0.24219508	FALSE
## 63	0.00000	0.00	0.01	6919	2713	2023-05-02	13:29:09	0.22657023	FALSE
## 64	-50.00000	0.00	0.01	15409	22317	2023-05-02	13:39:07	0.20703918	FALSE
## 65	0.00000	0.00	0.01	8791	5899	2023-05-02	13:39:54	0.19141434	FALSE
## 66	-50.00000	0.01	0.02	17673	5022	2023-05-02	13:40:26	0.18946123	FALSE
## 67	-50.00000	0.01	0.02	14197	9733	2023-05-02	13:40:13	0.17188328	FALSE
## 68	0.00000	0.01	0.02	29355	3808	2023-05-02	13:40:27	0.15235223	FALSE
## 69	-33.33334	0.02	0.03	47451	6341	2023-05-02	13:41:30	0.14161015	FALSE
## 70	0.00000	0.03	0.04	81694	6589	2023-05-02	13:41:14	0.12793841	FALSE
## 71	100.00000	0.06	0.07	116447	6427	2023-05-02	13:41:51	0.11866116	FALSE
## 72	233.33334	0.10	0.11	231235	7371	2023-05-02	13:41:45	0.10596597	FALSE
## 73	400.00000	0.20	0.21	261765	7129	2023-05-02	13:41:52	0.09742114	FALSE
## 74	683.33340	0.47	0.48	212092	19718	2023-05-02	13:41:37	0.09888596	FALSE
## 75	1100.00000	0.95	0.96	138686	12876	2023-05-02	13:41:30	0.10474528	TRUE
## 76	1192.30770	1.65	1.69	161717	18894	2023-05-02	13:41:23	0.12037012	TRUE
## 77	1040.90890	2.48	2.57	146138	17906	2023-05-02	13:40:40	0.14307498	TRUE
## 78	782.50000	3.48	3.59	114886	18416	2023-05-02	13:40:14	0.18091639	TRUE
## 79	551.47046	4.42	4.56	35146	18710	2023-05-02	13:39:44	0.20850401	TRUE
## 80	406.25006	5.42	5.55	12375	16442	2023-05-02	13:35:06	0.23731231	TRUE
## 81	272.15906	6.42	6.56	5281	8486	2023-05-02	13:39:03	0.26880614	TRUE
## 82	205.20000	7.39	7.53	1222	2595	2023-05-02	13:36:41	0.29102271	TRUE
## 83	144.66856	8.45	8.59	1795	1241	2023-05-02	13:40:41	0.33203793	TRUE
## 84	117.79279	9.41	9.56	854	224	2023-05-02	13:31:35	0.35254554	TRUE
## 85	111.74313	10.41	10.59	363	801	2023-05-02	12:57:16	0.38672488	TRUE
## 86	92.19744	11.41	11.57	41	53	2023-05-02	13:07:03	0.40820904	TRUE
## 87	83.60433	12.41	12.59	11	11	2023-05-02	11:45:43	0.43897045	TRUE
## 88	81.81818	13.37	13.57	14	11	2023-05-02	12:15:17	0.45947806	TRUE
## 89	77.51093	14.41	14.60	9	5	2023-05-02	11:40:23	0.49268085	TRUE
## 90	62.09598	15.41	15.57	1	0	2023-05-02	10:52:45	0.50928225	TRUE
## 91	0.00000	16.41	16.59	13	0	2023-05-01	15:59:36	0.51172363	TRUE
## 92	54.50121	17.41	17.59	3	14	2023-05-02	11:12:35	0.53516090	TRUE
## 93	42.34875	19.39	19.57	10	9	2023-05-02	13:07:06	0.57422301	TRUE
## 94	25.46666	20.41	20.59	1	1	2023-05-01	10:29:54	0.60449614	TRUE

3.2 For calls and puts of each expiration date, add a column of "Price", which is the average of "Bid" and "Ask".

```

SPY.option<- getOptionChain("SPY", NULL)
for (i in 1:length(SPY.option)) {

  SPY.option[[i]]$calls$Price<-0.5*(SPY.option[[i]]$calls$Bid + SPY.option[[i]]$calls$Ask)
  SPY.option[[i]]$puts$Price<-0.5*(SPY.option[[i]]$puts$Bid + SPY.option[[i]]$puts$Ask)
}
#head(SPY.options)

```

3.3 Choose 3 expiration date for put options, plot volatility smiles (Strike in x-axis and ImpliedVol in y-axis, similar to call smiles on page 22 of L9).

```

for (i in 1:length(SPY.option)) {
  SPY.option[[i]]$calls$Price <- 0.5*(SPY.option[[i]]$calls$Bid +SPY.option[[i]]$calls$Ask)
  SPY.option[[i]]$puts$Price <- 0.5*(SPY.option[[i]]$puts$Bid + SPY.option[[i]]$puts$Ask)
}
sigma <- 0.2
bisection.new <- function(f, a, b, tol = 0.001, N.max = 100){
  f.a <- f(a)
  f.b <- f(b)
  if(f.a*f.b > 0){
  }else if(f.a == 0){
    return(a)
  }else if(f.b == 0){
    return(b)
  }else if(is.na(f.a*f.b)){
    return(NA)
  }
  for(n in 1:N.max){
    c <- (a+b)/2
    f.c <- f(c)
    if(f.c == 0 || abs(b - a) < tol){
      break
    }
    if(f.a*f.c < 0){
      b <- c
      f.b <- f.c
    }else{
      a <- c
      f.a <- f.c
    }
  }
  return(c)
}

bs.call <- function(S0, K, T1, sigma, r){
  d1 <- (log(S0/K) + (r+0.5*sigma * sigma)*T1)/(sigma*sqrt(T1))
  d2 <- d1 - sigma*sqrt(T1)
  S0
}

bs.put <- function(S0, K, T1, sigma, r){
  d1 <- (log(S0/K) + (r+0.5*sigma * sigma)*T1)/(sigma*sqrt(T1))
  d2 <- d1 - sigma*sqrt(T1)
  -S0*pnorm(-d1) + exp(-r*T1)*K*pnorm(-d2)
}

```

```

}
Vega <- function(S0, K, T1, sigma, r){
d1 <- (log(S0/K) + (r+0.5*sigma * sigma)*T1)/(sigma*sqrt(T1))
sqrt(T1)*S0*dnorm(d1)
}
dprice.diff <- function(sigma)Vega(S0,K,T1,sigma,r)
implied.vol<- function(S0, K, T1, r, price,type, method="bisection"){
price.diff.call <- function(sigma)bs.call(S0, K, T1, sigma, r) - price
price.diff.put <- function(sigma)price - bs.put(S0, K, T1, sigma, r)
if(method == "bisection"&&type=="call"){
return(bisection.new(price.diff.call, 0.01, 5))
}else{
return(bisection.new(price.diff.put, 0.01, 5))
}
if(method == "Newton-Raphson"&&type=="call"){
dprice.diff <- function(sigma)Vega(S0, K, T1, sigma, r)
return(Newton_Raphson(price.diff.call, dprice.diff, 0.25))
}else{
return(Newton_Raphson(price.diff.put, dprice.diff, 0.25))
}
}
}

```

3.4 Choose 3 expiration date for put options, plot volatility smiles (Strike in x-axis and ImpliedVol in y-axis, similar to call smiles on page 22 of L9).

```

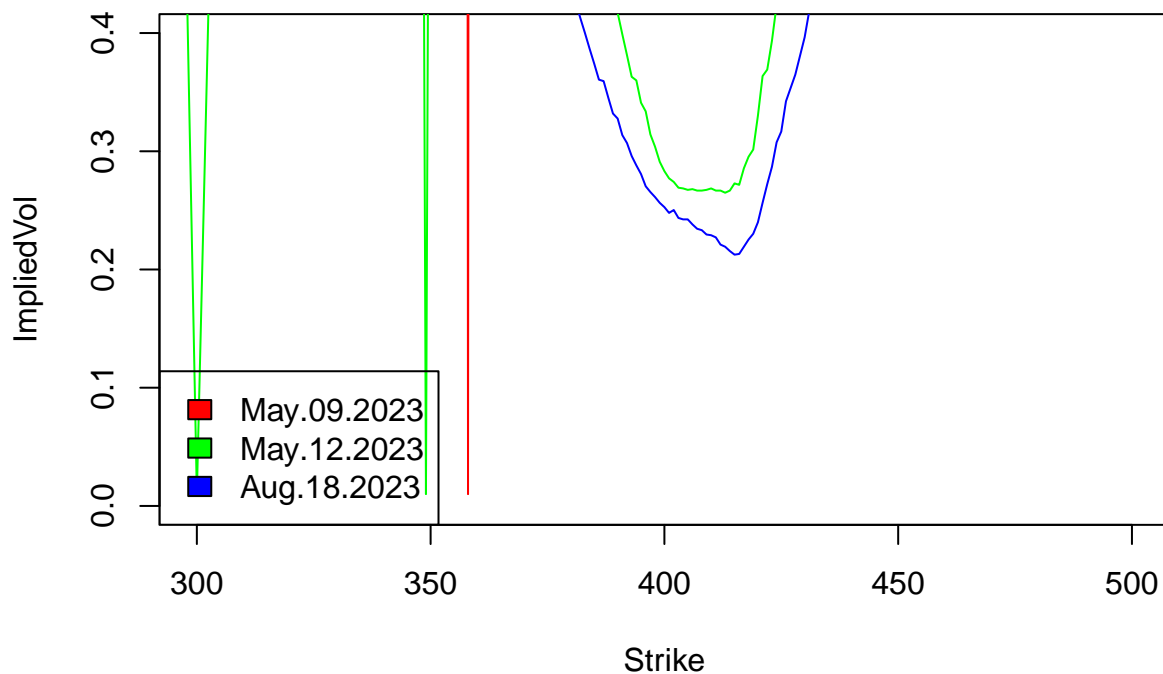
SPY.expiration <- names(SPY.option)
T.vec <- (as.Date(SPY.expiration,"%b.%d.%Y")-Sys.Date())/365
T.vec <- as.numeric(T.vec)
SPY.S0 <- getQuote("SPY")$Last
r <- 0.07 * 0.01
for(i in 1:length(SPY.option)){
  SPY.option[[i]]$calls$Price <- 0.5*(SPY.option[[i]]$calls$Bid + SPY.option[[i]]$calls$Ask)
  for(j in 1:nrow(SPY.option[[i]]$calls)){
    SPY.option[[i]]$calls$impliedVol[j] <-implied.vol(SPY.S0,SPY.option[[i]]$calls$Strike[j],T.vec[i],r,SPY.option[[i]]$calls$Price[j],
"calls")
  }
  SPY.option[[i]]$calls <-SPY.option[[i]]$calls[c("Bid", "Ask", "Strike","Price","impliedVol")]
}
for(i in 1:length(SPY.option)){
  SPY.option[[i]]$puts$Price <- 0.5*(SPY.option[[i]]$puts$Bid
+ SPY.option[[i]]$puts$Ask)
  for(j in 1:nrow(SPY.option[[i]]$puts)){
    if(is.na(SPY.option[[i]]$puts$Price[j])) {SPY.option[[i]]$puts$Price[j]=FALSE} else
    {if(SPY.option[[i]]$puts$Price[j]) {SPY.option[[i]]$puts$Price[j]}}
    SPY.option[[i]]$puts$impliedVol[j] <-implied.vol(SPY.S0,SPY.option[[i]]$puts$Strike[j],
T.vec[i],
r,
SPY.option[[i]]$puts$Price[j],
"puts")
  }
  SPY.option[[i]]$puts <-
  SPY.option[[i]]$puts[c("Bid", "Ask", "Strike","Price","impliedVol")]
}
}

```

```

plot(NA, xlim = c(300,500), ylim = c(0,0.4), xlab = "Strike",
     ylab = "ImpliedVol")
lines(SPY.option[[1]]$puts$Strike,
      SPY.option[[1]]$puts$impliedVol,col = "red")
lines(SPY.option[[2]]$puts$Strike,
      SPY.option[[2]]$puts$impliedVol,col = "green")
lines(SPY.option[[3]]$puts$Strike,
      SPY.option[[3]]$puts$impliedVol,col = "blue")
legend("bottomleft", SPY.expiration[c(6,9,17)],
      fill = c("red","green","blue"))

```



3.5 Keep fields “Strike”, “Bid”, “Ask”, “Price”, and “ImpliedVol” and save the calls and puts of each expiration date in .csv file. Submit one of the .csv file also.

```
print(getwd())
```

```
## [1] "/Users/akshaypatade/Desktop/FE515"
```

```
setwd("/Users/akshaypatade/Desktop/FE515/")
Sys.Date()
```

```
## [1] "2023-05-02"
```

```
(today <- format(Sys.Date(), "%Y_%m_%d"))
```

```
## [1] "2023_05_02"
```

```
(Exp <- names(SPY.option))
```

```
## [1] "May.02.2023" "May.03.2023" "May.04.2023" "May.05.2023" "May.08.2023"  
## [6] "May.09.2023" "May.10.2023" "May.11.2023" "May.12.2023" "May.19.2023"  
## [11] "May.26.2023" "Jun.02.2023" "Jun.09.2023" "Jun.16.2023" "Jun.30.2023"  
## [16] "Jul.21.2023" "Aug.18.2023" "Sep.15.2023" "Sep.29.2023" "Oct.20.2023"  
## [21] "Dec.15.2023" "Dec.29.2023" "Jan.19.2024" "Mar.15.2024" "Mar.28.2024"  
## [26] "Jun.21.2024" "Dec.20.2024" "Jan.17.2025" "Mar.21.2025" "Dec.19.2025"
```

```
Exp <- as.Date(Exp, format = "%b.%d.%Y")  
for (i in 1:length(Exp)) {  
  write.csv(SPY.option[[i]]$calls,  
    file = paste0("data",today,"Exp",Exp[i],"calls.csv"))  
  write.csv(SPY.option[[i]]$puts,  
    file = paste0("data",today,"Exp",Exp[i],"puts.csv"))  
}
```