ENV 790.30 - Time Series Analysis for Energy Data | Spring 2023

Assignment 6 - Due date 03/06/23

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Directions

You should open the .rmd file corresponding to this assignment on RStudio. The file is available on our class repository on Github. And to do so you will need to fork our repository and link it to your RStudio.

Once you have the file open on your local machine the first thing you will do is rename the file such that it includes your first and last name (e.g., "LuanaLima_TSA_A06_Sp23.Rmd"). Then change "Student Name" on line 4 with your name.

Then you will start working through the assignment by **creating code and output** that answer each question. Be sure to use this assignment document. Your report should contain the answer to each question and any plots/tables you obtained (when applicable).

When you have completed the assignment, **Knit** the text and code into a single PDF file. Submit this pdf using Sakai.

R packages needed for this assignment: "xlsx" or "readxl", "ggplot2", "forecast","tseries", and "Kendall". Install these packages, if you haven't done yet. Do not forget to load them before running your script, since they are NOT default packages.

Questions

This assignment has general questions about ARIMA Models.

Packages needed for this assignment: "forecast","tseries". Do not forget to load them before running your script, since they are NOT default packages.\

```
#Load/install required package here
library(forecast)
```

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

```
library(tseries)
```

Q1

Describe the important characteristics of the sample autocorrelation function (ACF) plot and the partial sample autocorrelation function (PACF) plot for the following models:

- AR(2)

  Answer: The AR(2) shows a strong autocorrelation and a gradual decay of autocorrelation with increasing lag in the acf of the model. The pacf of AR(2) will identify the order of the AR model (p=2), which shows significant spikes in the first two lags and cutoff after the lag 2.

- MA(1)

Answer: The acf of MA(1) will identify the order of the model (q=1), meaning that there is a significant spike at lag=1 and cutoff after lag 1. The pacf of MA(1) will decay exponentially.

Q2

Recall that the non-seasonal ARIMA is described by three parameters ARIMA(p, d, q) where p is the order of the autoregressive component, d is the number of times the series need to be differenced to obtain stationarity and q is the order of the moving average component. If we don't need to difference the series, we don't need to specify the "I" part and we can use the short version, i.e., the ARMA(p, q). Consider three models: ARMA(1,0), ARMA(0,1) and ARMA(1,1) with parameters $\phi = 0.6$ and $\theta = 0.9$. The ϕ refers to the AR coefficient and the θ refers to the MA coefficient. Use R to generate $n = 100$ observations from each of these three models

```
#ARMA(1,0)
ARMAmodel_1<- arima.sim(model=list(ar=0.6), n=100) #the AR coefficient is 0.6
ARMAmodel_1
```

```
## Time Series:
## Start = 1
## End = 100
## Frequency = 1
##   [1]  0.01549904 -0.07088119 -0.34782126 -0.61436954  0.28331676 -0.33946546
##   [7]  0.48596117  1.99047884  2.61765370  1.33231524  2.08473431  2.07392094
##  [13]  1.69112502  0.08556690 -0.06747913 -1.12299997 -0.30456470  0.38875833
##  [19]  0.54925523  1.47319859  1.08977130 -0.06230389  1.25036228  0.69395542
##  [25] -0.69536152 -1.04711404 -2.15968405  0.09528470 -1.06246664  0.47627875
##  [31] -0.57900816 -0.65897253 -0.16256863 -0.00801316 -0.71894681  0.30045056
##  [37]  0.18204594  1.71072085  0.93175311 -1.24777211 -1.30120793 -0.74708613
##  [43]  0.41827115  2.40220130 -1.16195203 -1.44698211 -0.60187424  0.44868888
##  [49]  0.59177633  0.49072489 -1.67298270 -0.11886158  0.13395503 -0.13516206
##  [55] -1.08529030 -0.29969447  1.17972291  1.57062904 -0.65882984  0.74553681
##  [61]  1.57377819  1.39112809  0.48346359 -0.54189665 -1.24632865 -1.32177578
##  [67] -0.56216376  0.04502444 -1.99015883 -0.46430497  0.12739144 -1.39034435
##  [73] -2.62331825 -1.31938819  0.17143733  1.31204404  2.84222455  2.45455744
##  [79]  0.50178736  0.29342366  2.66070833  1.99898692  0.86891956  2.03539457
##  [85]  1.51605462  2.14527993  0.98283323  0.30983802 -0.18416896 -0.19625864
##  [91]  0.43911781 -0.94206202 -1.30852587  0.60669073 -0.64690201  1.35454137
##  [97]  0.25656244  0.12711458  1.11905363 -0.56771207
```

```
#ARMA(0,1)
ARMAmodel_2<- arima.sim(model=list(ma=0.9), n=100) #the MA coefficient is 0.9
ARMAmodel_2
```

```
## Time Series:
## Start = 1
## End = 100
## Frequency = 1
##   [1] -1.91005461 -1.98897203 -0.67173670 -1.64301019 -0.83368116  0.87793626
##   [7]  2.61321087  2.58528532  0.95942995  1.21512651  2.82848545  1.57686004
##  [13] -1.33657053 -1.19549484 -0.37483624  0.77734207  2.05897190  0.60844052
##  [19]  0.46831852  0.97193687 -0.85695375 -1.37461610 -0.39304790 -0.19636459
##  [25] -0.51690240 -0.25952791  0.73351200 -1.09417289 -1.10354585  0.37071345
##  [31]  0.38057718  0.12526454 -0.77433586 -1.89894270 -1.48080945 -1.32672595
##  [37] -2.29986648 -0.84699703 -1.26600992 -0.81508859  0.38758601 -0.40631188
##  [43]  0.18058657  1.49204085  2.24414307  0.89304737 -0.68853642  1.10174121
##  [49]  0.86763430 -0.34519028 -0.38219628 -0.66035043  0.87631008  0.77210235
```

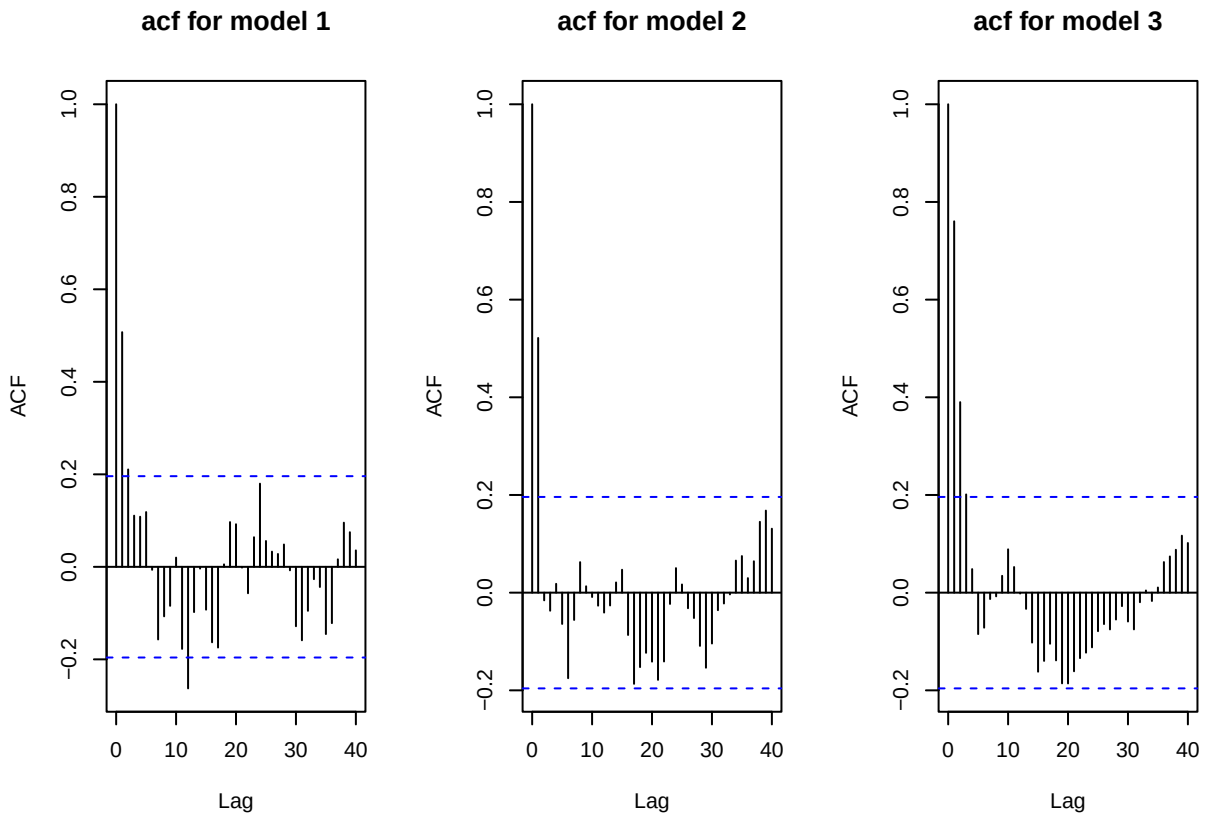
```
##  [55]  1.94512972  2.48548129  0.44568216  0.88149285  1.53505595  0.22452248
##  [61] -2.41729749 -4.61457641  0.07241557  3.23401473  0.32110693 -0.64238344
##  [67] -0.48823575  0.21861824 -0.37060154  1.02737754  1.97296182  1.04752660
##  [73]  0.63402713 -1.05889890 -2.85666171 -3.29949197 -1.36837377  0.20468565
##  [79]  0.38295016 -0.25779681 -0.95662340 -0.86500853 -0.48992799 -0.69726615
##  [85] -0.71469426 -0.49332406  0.57632305  0.82783073  0.39678275  1.72533689
##  [91]  1.24091003 -1.81824307 -1.40480708  1.18694364  2.48417763  0.30858354
##  [97] -0.67109389  1.78302549  1.49573961 -0.37625701
```

```
#ARMA(1,1)
ARMAmodel_3 <- arima.sim(model=list(ar=0.6, ma=0.9), n=100)
ARMAmodel_3
```

```
## Time Series:
## Start = 1
## End = 100
## Frequency = 1
##   [1]  1.51561120  3.57472785  2.87144566  1.91816244  2.22388314  2.21916656
##   [7]  2.17448199  1.75489140  1.79871775  1.65805470  0.05667639 -2.15064601
##  [13] -2.17190531 -0.23648987  1.20544397  2.12312492  1.63561018  1.22291081
##  [19]  2.51216802  1.75802584 -1.91749154 -3.07177215 -2.45800117 -3.58991781
##  [25] -3.70243379 -1.13968793 -0.92139114 -3.29636301 -4.93362999 -4.00936363
##  [31] -0.78428436  0.26629307 -1.43447247 -0.92613314 -0.14798161  0.32302051
##  [37]  1.03124457  0.92165661 -0.63191108 -1.81532335 -0.76647599 -0.01456510
##  [43] -0.18868673  2.02176227  3.49731976  0.71703184 -1.50724706 -0.79457700
##  [49] -0.87336677 -2.21528139  0.08734520  1.79757504  0.03880806  0.13722641
##  [55]  2.09963144  0.75424170 -0.65759903  1.82278628  3.53629801  2.59249105
##  [61]  2.29600925  1.93191745 -0.69095225 -1.88058380 -2.56926399 -4.60471469
##  [67] -4.65776531 -2.37620137 -0.44198558  0.97651304  1.96450133  0.69401513
##  [73]  0.13525138  0.62432905 -0.12469865 -0.97086768 -1.26910163 -0.38807277
##  [79] -0.44841087  0.17638917  2.26957649  2.43627154  3.15645752  4.54536506
##  [85]  3.69005841  1.63530536  0.11169785 -0.25078480 -0.56875643  0.32758411
##  [91]  3.37911630  4.46115707  2.67484898 -0.57573165 -1.71598793 -0.68938941
##  [97] -0.43632141 -1.38506194 -1.95352520 -1.82790728
```

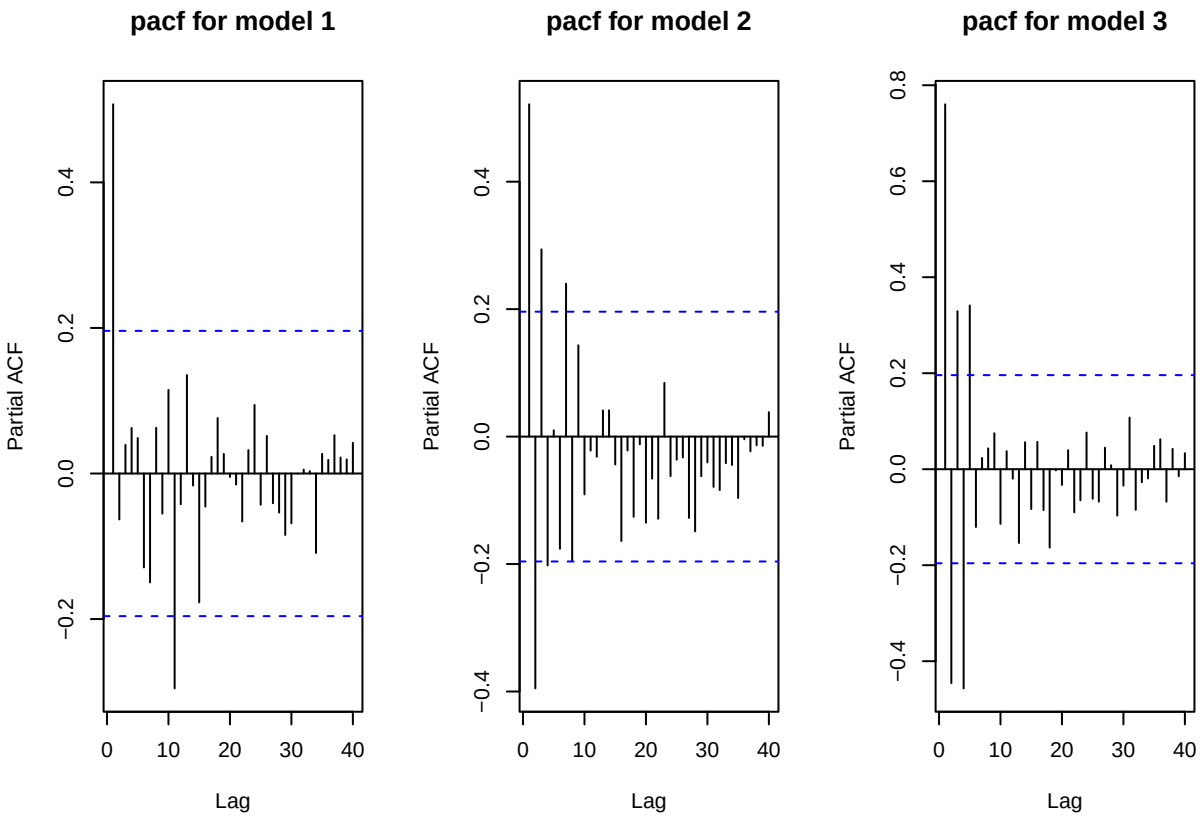
(a) Plot the sample ACF for each of these models in one window to facilitate comparison (Hint: use command $par(mfrow = c(1, 3))$ that divides the plotting window in three columns).

```
par(mfrow=c(1,3))
acf(ARMAmodel_1, lag.max = 40, main = "acf for model 1")
acf(ARMAmodel_2, lag.max = 40, main = "acf for model 2")
acf(ARMAmodel_3, lag.max = 40, main = "acf for model 3")
```



(b) Plot the sample PACF for each of these models in one window to facilitate comparison.

```
par(mfrow=c(1,3))
pacf(ARMAmodel_1, lag.max = 40, main = "pacf for model 1")
pacf(ARMAmodel_2, lag.max = 40, main = "pacf for model 2")
pacf(ARMAmodel_3, lag.max = 40, main = "pacf for model 3")
```



(c) Look at the ACFs and PACFs. Imagine you had these plots for a data set and you were asked to identify the model, i.e., is it AR, MA or ARMA and the order of each component. Would you be identify them correctly? Explain your answer.

Answer: Model 1 is AR, model 2 is MA, model 3 is ARMA. Model 1 is AR model because ACF will decay exponentially with time, and we found that it is decaying with lags in the ACF of model 1. Model 2 is MA model because pacf has slow decay, while it is not obvious in the above graph. Model 3 is ARMA model because in the PACF initial values dependent on the AR followed by the decay due to the MA part.

(d) Compare the ACF and PACF values R computed with the theoretical values you provided for the coefficients. Do they match? Explain your answer.

Answer: The AR model somewhat matches with the theoretical value. We set phi=0.6, meaning that the coefficient of AR should be 0.6. However, sometimes we can find that the pacf of lag 1 is 0.6 for model 1, but pacf of lag 1 is not 0.6 when we rerun the ARMA again. It didn't match with the theoretical value for MA model since we didn't find 0.9 at lag 1. For the ARMA model, ar coefficient at lag 1 in pacf didn't match with the theoretical value (0.6), but ma coefficient at lag 1 in acf matches with the thoretical value (0.9).

(e) Increase number of observations to $n = 1000$ and repeat parts (a)-(d).

```
#ARMA(1,0)
ARMAmodel_1_new<- arima.sim(model=list(ar=0.6), n=1000) #the AR coefficient is 0.6
ARMAmodel_1_new
```

```
## Time Series:
## Start = 1
## End = 1000
## Frequency = 1
##    [1] -0.488958669  0.128683733  0.897218546  0.619568285 -0.194988460
```

```
##    [6] -0.607982694 -1.516425161 -1.865441957 -1.071599916 -2.167007423
##   [11] -2.555360865 -1.056007094 -0.715460399 -0.399182184 -0.029208792
##   [16] -0.464644186 -2.209202169 -1.512207736 -0.918252377 -0.482506122
##   [21] -0.552609391  1.055056942  0.420315711 -0.202570437  1.063899169
##   [26]  0.983922748 -1.197979225  0.164828529 -0.520446045  1.925831002
##   [31]  2.044451674  1.820121736  2.233760383  1.244021145 -1.305458656
##   [36] -0.691668838 -1.152443633  0.854965188  0.428169742 -0.874485959
##   [41] -1.407566951 -1.913985527  0.538464626 -0.209388913 -0.903381478
##   [46] -0.907048122  0.520822819  0.600640478 -0.324469946 -0.297567801
##   [51] -0.374639119 -0.941265543 -0.937966902  0.086405166 -0.713029681
##   [56]  0.098330167  0.294153432  0.050482034  0.709622017  1.481991373
##   [61] -0.016554641 -1.469338772 -1.143844915 -1.590646659 -0.388811641
##   [66] -0.466310150 -0.254038780  1.733968699  1.112334468  0.873455957
##   [71]  1.525760496  1.481662942  1.481418633  1.258076223  0.723597465
##   [76] -0.198077126  1.980348979  0.676173797  0.559088609  2.837493212
##   [81]  1.000014489 -0.964122674 -0.526745100 -1.446525453 -0.930774476
##   [86]  0.268751830  0.362526628 -0.416807829 -0.789457100 -0.660865542
##   [91]  0.459628501  1.119803752  2.732304333  1.914585226  1.317469482
##   [96] -0.135560389 -1.129422206 -1.171908231 -0.391755105 -1.060384266
##  [101] -1.971197316 -0.600146050 -0.294854327  0.618901822  0.534990192
##  [106]  1.384674804  1.662531490  1.351393027  1.743002345  0.096682062
##  [111] -1.682333358 -1.571775842  0.061476436 -0.840650950 -2.805156681
##  [116] -1.619211736 -1.735877183  1.092242083  2.846777369  0.017450642
##  [121]  1.251588704  1.275006747  1.358525483  1.563456719  0.802017400
##  [126]  1.350499065  0.049182905  0.123777274  0.606577338 -0.043036690
##  [131] -0.054633743  0.406802435 -0.875313714 -0.856840742  0.168255559
##  [136]  1.179716862  1.051129950  0.631037774  1.017722660  1.337654377
##  [141]  0.357754719  0.504698176  1.635624540  1.527541469 -0.833153816
##  [146] -0.883583596 -3.100965723 -2.876751305 -2.023612360 -2.808092507
##  [151] -0.267271887  1.321691841  2.693108050  0.258476505  0.060431138
##  [156] -0.290126366 -0.119935579 -0.722056963 -0.996430913 -2.246723202
##  [161] -2.875302775 -2.293585520 -0.976814674  0.242385742  0.088695083
##  [166] -0.983143415 -1.554424692 -1.667406012  0.427355647  0.736419665
##  [171]  0.530627502 -0.245319630 -0.523778529 -0.500453944 -1.282777634
##  [176] -0.537122721 -0.230462369  0.449677035 -0.331493143 -0.937395512
##  [181]  0.768208082 -0.306662871  1.489838302  2.137190931  2.106106133
##  [186]  0.376249342 -2.585645032 -0.551732071  0.590372429  0.194840680
##  [191]  0.817039347  0.139175753  1.335117107  1.597360198  0.824897216
##  [196] -0.232720930  0.890686983 -0.208221967  0.644431643  0.599855593
##  [201] -0.607238480 -2.051377858 -1.662814445 -0.886590859  0.307746068
##  [206]  1.918367191  0.845644793  1.409322867  1.947083613  2.055598594
##  [211]  1.283094116  0.786281014  0.427161939 -0.090882080  0.317232922
##  [216]  0.395138053  0.183216593 -0.528052765  1.117210284  1.011310642
##  [221] -0.490551077 -0.968876404 -1.274098832 -2.014610602 -3.162963932
##  [226] -2.474281075 -0.558647794  0.753356539  1.081982160 -1.148450019
##  [231]  0.512589898 -0.566956209 -0.232583017  1.703370271  0.984180049
##  [236]  1.645782798  1.632483702  1.335205281  0.234421187  1.402223011
##  [241]  1.798823048  1.167556973 -0.072769615  0.999464698  1.513300828
##  [246]  1.059075046  1.314511375 -0.080020093  0.959414490  0.058081138
##  [251] -0.358274835 -0.521991279 -1.295898900 -1.359889845 -0.091715241
##  [256] -0.774150715 -0.955755178 -2.040416531 -1.007260548 -0.173280506
##  [261]  0.263503550 -0.357726809  1.068083676  2.001454077  1.159165946
##  [266] -0.666217998 -1.879095270  0.470808371  0.588919353  0.490873828
##  [271]  0.130536006  0.754688402  1.402889504  0.689764348  0.953325060
```

```
##  [276]  0.527256805  0.359429738 -0.204097675  0.509859488  0.361382810
##  [281] -0.215895510  0.091353481  0.283282050 -0.940034953 -0.100677553
##  [286] -0.189549425 -0.220673481  0.820986152  0.111697347 -0.931342253
##  [291] -1.197737147 -2.563836021 -1.191599784  0.056594464  0.669330326
##  [296]  0.828101817  1.110116918 -1.010658259 -1.125001398 -0.468550482
##  [301] -0.047761298 -1.210288582  0.096686091 -0.425174890 -2.276953334
##  [306] -2.574420680 -0.080872993  0.455070867  0.651166642 -0.185085329
##  [311]  0.306290751 -0.521750288 -0.572454451  0.437275445 -0.888064771
##  [316] -1.743121431  0.176174793 -0.031817205  0.383264035 -1.643166425
##  [321] -1.117841093 -2.234528557 -0.728734744 -1.133532138  0.413513068
##  [326]  0.512961573 -0.648155772  0.599898440  0.143330290 -1.090048647
##  [331] -0.163463441 -0.272834525  0.146357404 -0.466527683 -0.599891460
##  [336] -1.587613143 -1.401157365  0.372364040 -0.460105558  1.067540512
##  [341]  1.312075844  1.328624702  1.259249864  1.055771075  0.017287292
##  [346] -0.257807384 -0.032738580  1.694788735  0.157987078  0.189591773
##  [351] -0.384906093 -0.501299964 -0.411454657 -0.393525448 -1.396445130
##  [356] -1.236263632 -1.555137386 -1.815000219 -1.398748721 -2.179327620
##  [361] -1.047775497 -1.314642995 -0.691471432  1.204240236  1.272231810
##  [366]  0.421579420 -0.137267501 -0.400632415 -0.275022142 -0.684116614
##  [371] -0.935209964 -0.763378259 -0.484882957 -1.769804427 -0.050349363
##  [376]  1.079417653  0.944889389  1.172067101  1.799884220  0.036751909
##  [381]  1.030204979 -0.412452635 -0.078159020  0.503553665  1.114564744
##  [386]  0.086790370 -0.418566670  0.637845072  0.053186796 -0.636284976
##  [391]  0.330896952  0.787502523  0.361852822 -0.241318376 -1.232460280
##  [396] -0.427082099 -0.351342542  1.137696634  1.392235631 -0.922692718
##  [401] -0.641118766 -1.424708926  0.505299668  0.538081081 -0.913826950
##  [406] -1.024731067  0.032150667 -0.463527038 -0.263657751 -0.427817126
##  [411] -1.143523675 -2.204943458 -1.821692268 -0.947044694  1.247905863
##  [416]  1.769758308  0.167248606 -0.055790565 -1.003241916  0.761972911
##  [421]  1.139473273  0.416322427  1.829855608  0.858535377 -0.556246530
##  [426] -1.958543952 -2.826937740 -0.777527294  0.573800007  2.251843975
##  [431]  1.663870482 -0.292183454 -2.025293554 -1.895161894 -0.374911930
##  [436] -2.001642598 -2.967104879 -2.468764738 -2.989102328 -1.701960611
##  [441] -0.731781927 -0.734345962 -1.473061776 -1.440223131 -0.628030337
##  [446] -1.425296434 -0.915273927  0.136969615  1.429213013  2.540370654
##  [451]  0.139705240 -1.316363958 -1.615595724 -2.134434591 -1.267555168
##  [456] -2.307917186 -1.799995733 -1.480713953  1.537528175  0.662679135
##  [461]  2.084341994 -0.145868476  0.245808497  1.304449004  1.602329733
##  [466]  2.893699927  2.496298893  1.943517828  1.184656442  0.871609000
##  [471] -0.983562828  0.502454038  1.569251420  0.340032764  1.355220433
##  [476] -0.191939268 -1.443066614  0.081270834 -1.157889939 -2.167177557
##  [481] -2.332703433  1.469304913  0.498026311  1.510553066 -0.288472630
##  [486]  0.316376907 -0.305587793  1.637677506  0.191787629 -0.586793744
##  [491] -1.248457779  0.575575098  0.272058774  0.249445458 -0.367261079
##  [496] -0.628932102 -0.804499764 -0.853437439 -0.349221302 -1.013636343
##  [501]  0.274864538  0.866009199 -0.293214855  0.722125142  0.995026678
##  [506]  2.125299000  2.476049263  0.747642980  1.299044375  0.404404652
##  [511]  1.551212798  0.792515256 -0.545330455 -1.438128832  0.429048137
##  [516]  0.060227600 -0.895122492  1.250901326 -0.304090230 -0.536476600
##  [521] -1.034631793 -1.553837472 -0.304983490 -1.117700509 -0.710809171
##  [526] -2.074043396  0.196945363 -1.325404667 -0.817854948 -1.126489725
##  [531] -1.143471423 -0.370089885 -0.208881672  0.459703613 -1.629977890
##  [536] -0.066552480  0.692045836 -0.837138477  0.654349131 -0.174845661
##  [541]  0.312218197  0.534662606  0.952581667  0.972230835  2.462397176
```

```
##  [546]  1.820274133  0.383827604 -1.629063170 -2.028613582 -1.932256165
##  [551] -0.148832004 -1.642653185 -0.664407954  0.090768397 -0.082930293
##  [556] -1.093764703  0.337255747  0.411607438 -0.255305218  0.624477179
##  [561]  0.633103151  2.737806818  2.112632215  1.402102046  1.181294803
##  [566]  0.633109099 -0.673959620  0.357609927 -0.062351776  0.300063313
##  [571]  0.038074259  1.437302880  1.509078520 -0.968410032 -0.786151424
##  [576]  0.059856673  1.604655717 -0.257130582  1.058508187  0.433134897
##  [581] -0.833062339  1.253928197  1.042015250 -1.174232958 -1.311795313
##  [586] -1.193627340 -1.549292049 -1.149935199 -2.308699115 -0.478343407
##  [591]  0.348974614  0.445744743  0.812254688  2.067861485  1.503460390
##  [596]  1.667609496  0.412088707  0.503770088  0.735100695 -2.149741496
##  [601] -0.471593220 -0.300050905 -0.280594534 -0.482289486 -0.159725166
##  [606]  0.723752251  1.327746703  0.450966286  0.913489948  2.170595089
##  [611]  0.973068696  0.860895585 -0.193674411 -1.882187306 -1.462166949
##  [616]  0.014138003 -0.437480182  0.303820532 -1.105766202 -0.818201903
##  [621] -0.305177504 -1.205070000 -0.695757235 -0.305764773 -0.008614009
##  [626]  0.884829917 -0.382198851 -0.842802358 -0.122665858  0.064120135
##  [631] -0.714586585 -0.826567460  0.620332923  1.397985693  1.779525061
##  [636] -1.149733675 -1.169755147  0.782535487 -0.426421173 -0.407763414
##  [641] -0.586113114 -1.076188169 -0.841138760 -0.368181937  0.966635981
##  [646]  1.559989625  1.710068692  0.016420781 -0.231548829 -0.665872539
##  [651] -0.726290541  0.581292070  0.838360555  2.628618826  2.629096456
##  [656]  1.936379645  2.849289484  1.711810864  2.229815777 -0.527265993
##  [661] -0.140210295 -0.343397472 -0.002496108 -0.232971472 -1.535371030
##  [666] -2.850005194 -0.070822269  0.443386393 -0.101263278  0.572615815
##  [671]  1.273343710  2.475530478  0.999289908  0.434983267  1.807659796
##  [676] -0.447790641  1.623050945  1.549695021  0.556790125  0.507196354
##  [681] -1.014453886 -1.446691706 -0.204543486 -0.190771944  0.332505717
##  [686]  0.873459815  1.542870656  2.298439643  1.374357113  1.813205824
##  [691]  0.938591675  0.007975598  1.069399723  1.046042689  0.909014493
##  [696]  1.666486394  1.272466333  0.613570285 -1.015508117 -0.406229696
##  [701] -0.247092310 -0.822426276 -1.227652233 -0.952649462  0.991587298
##  [706]  2.241690829  2.308278995  0.569284094 -0.894132587 -2.563419821
##  [711] -2.003859876 -0.172232029 -0.583109551 -0.387295255  0.863562188
##  [716]  2.083213570  0.543272900 -1.835345560 -1.360921746  0.068474494
##  [721] -1.647917683 -2.298409705 -1.493639348 -1.319307601 -0.432838066
##  [726] -1.029925922 -1.008311994 -0.298058063 -0.001179363 -0.138010696
##  [731]  1.722686102  2.297786724 -1.098423080 -0.857304262  0.697692475
##  [736]  1.094178278  2.723650197  1.153496382  0.620721842 -0.087537474
##  [741] -0.585968641 -1.561279771  0.208462516  0.806407408  0.482664612
##  [746]  1.146118450  1.387607741  3.294084501  1.162382028  0.174088961
##  [751] -1.084616629 -0.094467883  0.159783039  1.504705761 -0.525176458
##  [756] -0.907849474 -0.224978852  0.086182308 -1.450818688  1.050466751
##  [761] -0.131321155 -0.574142932 -0.319981396  0.156316703 -0.975977850
##  [766] -1.018071979  0.604058285  0.148407087 -1.042277458 -0.452547347
##  [771] -1.131700188  0.144160722  1.438542659 -0.570705002  0.752180868
##  [776]  0.290496563  0.006830768 -0.455474432  0.729998610  3.328711368
##  [781]  2.803678092  2.507300914  0.330574756 -0.508214472 -0.126546769
##  [786]  0.123987039  0.584558883 -0.788252781 -0.597522077 -1.080072488
##  [791]  2.335641530  2.027453869  1.683188456  1.832599624  0.814815902
##  [796]  0.546078634  1.201461518  0.272636994  0.334762070  0.930782524
##  [801] -0.510874397  0.030213807 -0.246601819 -0.455580057 -1.755403216
##  [806]  0.981677883 -0.079218540  0.789605427  0.362685886 -0.660959843
##  [811] -1.025148137 -1.286709718 -1.666739443 -0.777308741 -0.349693911
```

```
##  [816] -1.218026452 -1.169596214  1.047309718  2.850333302  2.229817197
##  [821]  0.498552875  1.890568634  0.754249372  1.075441411 -0.818795730
##  [826] -0.450648564  0.207843816  1.060332762  2.179489306  1.753997111
##  [831]  2.250307230  2.008920859  1.946271039 -0.399025930 -0.969887562
##  [836]  1.413818296  0.447583310  0.909767815 -0.276107851 -0.879860565
##  [841] -0.779196101 -1.789079867  1.002395926  2.937467205  2.127800064
##  [846]  1.024924033  0.145529031  1.401074729  0.499781311  1.572954811
##  [851] -0.643884123  2.109070271  1.604312631  0.905496656  0.368056250
##  [856]  0.425671149 -0.344099421  0.981115079  0.742805853  1.036281719
##  [861]  1.742592977  1.883625886  1.234425284  2.644697198  0.935222046
##  [866]  0.728958374  0.965799512  1.014452993  0.116614198  1.631913871
##  [871]  0.765593946  1.247163883  0.755835639  0.698276218  0.365883280
##  [876] -1.623713138 -0.300271135  0.049835564  1.368240004 -0.102928806
##  [881]  0.672573664 -0.134967542 -0.563238014  1.230978252  0.629060658
##  [886] -0.457308592 -1.165605593 -0.552855512  0.498972696 -0.066356491
##  [891] -0.501723389 -0.835626206  0.079131301  0.289013629 -1.631724192
##  [896] -0.054137646 -0.898934185 -0.607896013 -0.233416259  1.075878954
##  [901]  1.056093544 -0.119628722 -0.363133517 -2.117013376 -2.226529242
##  [906] -0.891739505  1.178922400  2.471440621  1.557801343 -0.684069718
##  [911] -1.829039988 -0.910628128  0.993956163  1.465961433  1.897945612
##  [916] -0.271400257  0.592506376  0.569605473  0.554884654 -0.523736002
##  [921]  0.005857625  1.113970563  0.662422405 -0.400166928 -0.639520684
##  [926]  0.077413379 -0.688965229 -0.216699361  0.503291188 -0.660016476
##  [931] -0.005911302  0.929616876 -2.330120993 -1.795528635 -0.737655120
##  [936] -0.312444066  0.457305177  1.221030515  0.502625106 -0.515056230
##  [941]  1.372522169  1.122486126 -0.085992374 -0.066878797  0.645325257
##  [946]  1.183860815  0.177037317  1.291948624 -0.701795048 -1.474350762
##  [951]  0.603062988  2.178690656  1.976996821  0.914321880  0.100181558
##  [956] -1.052849930  1.421160853  0.680031998  1.109974219  0.431391949
##  [961] -0.319309048  0.475516209  1.947544229  3.417663807  2.143516306
##  [966]  1.208228827  1.386953111 -0.081470736 -0.589017016  1.666735032
##  [971] -0.009175304 -1.106446599  1.949954433  2.628046560  1.881629243
##  [976]  0.218936457 -0.280166410 -1.196775323 -1.322859820  0.127535727
##  [981]  0.024523397  0.384232329 -0.046344120 -1.626622182 -2.273502184
##  [986] -2.236112655 -2.983324302  1.085607554  0.935816512  0.584955346
##  [991]  0.605705412  1.397656310 -0.010386224 -1.494341374 -2.935726479
##  [996] -1.494996268 -0.963731584 -1.450405033 -0.500906979 -0.008219860
```

```
#ARMA(0,1)
ARMAmodel_2_new<- arima.sim(model=list(ma=0.9), n=1000) #the MA coefficient is 0.9
ARMAmodel_2_new
```

```
## Time Series:
## Start = 1
## End = 1000
## Frequency = 1
##    [1] -1.404578112 -2.118869455 -0.810877185  0.357346001 -0.674597267
##    [6]  1.131971329  0.709501015 -0.794464617  1.569798368  0.807878444
##   [11] -2.180101485  0.331217887  0.156780954 -1.439101524  0.385919517
##   [16] -1.255540477 -4.121854502 -1.514365753  1.343029853  1.062176586
##   [21] -0.365158669 -2.031975341 -1.325717571  0.131072248 -0.367374868
##   [26] -0.053007902 -0.359103445 -0.053146198 -0.326032461 -0.747494411
##   [31] -0.722689856 -1.970760161 -3.526795149 -3.320871740 -1.675020180
##   [36] -0.919167785 -0.226725185 -1.186676225 -1.579215094 -1.901432259
##   [41] -2.046046932 -0.744922564 -0.664447625  1.715135255  0.491514137
```

```
##   [46] -1.682699281 -1.837772903 -1.116636711  0.924457792 -0.306227772
##   [51] -1.725882613 -0.274405887 -1.060587208 -1.791386291  0.061860282
##   [56]  0.152791968  0.123305701 -1.291652981 -1.356828754  1.843344801
##   [61]  3.084270690 -0.561453509 -2.924523059 -0.913222804 -0.729479284
##   [66] -1.898255907 -1.275764564 -0.513463899  1.751664335  2.908063913
##   [71]  0.374080366  0.389077188  1.016451974  0.027919342  0.484422515
##   [76] -0.319977777 -0.810314272  1.780136069 -0.195425178 -3.331209048
##   [81] -2.193397278  0.004340358  0.205306756  1.058368473  0.928991548
##   [86] -1.825224038 -0.999771255  0.833685878  1.396970735  0.631795882
##   [91]  0.299668332 -0.470108331 -0.551330061  0.917019282  0.693033577
##   [96] -1.265258951 -2.271017545 -0.890678238  0.341624847  0.095402363
##  [101] -0.744557082 -1.206349593  0.220115069  1.785706115 -0.285719567
##  [106] -2.623829358 -1.536504481  0.628582234  0.186863253  0.538953449
##  [111]  1.231180728 -1.314379467 -0.851091664  0.567069771  0.279781884
##  [116]  1.642978509  0.804273623 -0.928092357 -1.678804864 -2.402778014
##  [121] -2.332036661 -0.958975944 -1.607438316 -2.071759904 -2.421944878
##  [126] -1.647053163  1.129215437 -0.111699152 -2.383982899  1.083807567
##  [131]  3.541971938  1.072772681  0.778046965  1.902842668  0.314544307
##  [136]  0.573015985  1.082669597 -1.359866426 -1.509161358 -0.247055481
##  [141] -0.590424306 -1.124856973  0.532162736 -0.945758061 -0.860745051
##  [146]  0.970185619  1.504497950  1.350300284  0.975843114  1.875960018
##  [151]  0.283448060 -2.605915092 -3.595197258 -3.304887125  0.429857774
##  [156]  0.151984942  0.014397133  1.514929203  0.160662937 -2.216588278
##  [161] -1.094052117 -0.415709303 -1.778865378 -1.519490090 -0.181924548
##  [166]  0.828847553  0.507011815  1.825489979  2.158671647 -0.695888056
##  [171] -2.810341404 -0.064963020  1.820375202 -1.419478975 -0.558646604
##  [176]  2.399577048  0.722760000 -0.974455529  2.237633699  1.935845244
##  [181] -0.048727736 -0.305575885 -1.946664540 -0.279702677  1.397986180
##  [186]  0.098863188 -1.247079369  0.263040306 -0.649444315 -2.308338740
##  [191]  0.169879859  0.388419390  1.134608504  1.695731279  0.176222278
##  [196]  0.853410720  0.551416531 -1.773719924 -0.782575952  0.194535738
##  [201]  0.854167674  0.995440768 -0.054435852  1.091325712  2.431370227
##  [206] -0.589223210 -2.642771302 -1.039173306  0.909613882  1.152536204
##  [211] -0.686705509 -1.133988116  0.114298621  1.008988272  0.257059425
##  [216]  0.151903858  0.151829607 -0.749728482 -1.404853099  0.031345279
##  [221]  1.694185646 -0.246289701 -0.784659787 -1.192353235 -1.204218998
##  [226]  0.658296075 -0.022773347  1.311913915  0.855975506 -1.048631976
##  [231] -0.354589087 -1.270883365 -1.842636365 -3.030333090 -2.585307227
##  [236] -1.244631167 -2.611634766 -2.232815296 -0.830544596 -0.142344266
##  [241]  0.508018348 -0.126435300 -0.085974203  0.947104745  0.986638114
##  [246]  0.155925410  1.330127658  0.700659425 -0.019043784  1.507795640
##  [251]  1.483091856  0.433095244 -0.041118196 -0.354991970 -1.145835680
##  [256] -1.067702245  0.494714335 -0.690295459 -0.103401453  0.886041040
##  [261] -0.583729699  1.128241249  1.591536735  2.428955228  4.296490300
##  [266]  1.692566877  0.262259291  0.416800446  0.265424104 -0.097684365
##  [271]  0.607943207  2.308430225  0.593236030  0.136235555  0.739349652
##  [276]  0.635906140  0.056490608 -0.274250322  1.820942021  1.082727141
##  [281]  0.062995553 -1.131267371 -2.882759616 -0.318915034  3.056306056
##  [286]  1.676781375  1.886077659  2.530540802  0.832818691  1.508996807
##  [291]  1.586203627 -0.685470266 -1.967767089 -0.620780610  0.376155365
##  [296]  0.091622753 -1.891218513  0.412466860  1.008459592 -1.394044074
##  [301]  1.712663451  0.671252869 -1.782209962 -0.566893627  1.699288261
##  [306]  1.584612156 -1.110516249 -1.313772433 -0.580633655  0.469827246
##  [311]  1.205786289  1.395496803 -0.103962852 -1.336499758 -0.278301402
```

```
##  [316]  1.357317523  0.685181808 -0.411490801  1.279841509  1.705410976
##  [321]  1.449019289 -0.050959837 -1.452249239 -0.169008785 -0.935066094
##  [326] -1.054843608 -0.037627464 -1.187919754 -1.181202922 -0.772618967
##  [331]  0.390577565  0.778159137 -0.001541372 -0.289234749 -0.486760493
##  [336]  0.217088122 -0.992665164 -1.595835299  0.225098591  0.458366366
##  [341]  0.222819609  0.323139934 -0.036324201 -1.226770128 -0.347896295
##  [346]  2.077037832  1.699285475 -0.056515835 -0.876855902 -0.376229842
##  [351] -0.598172329 -0.603725059  0.432292737 -0.670582686 -1.258749135
##  [356] -0.510588254  0.280586618 -0.042109815 -0.355250029  2.659638576
##  [361]  2.164175865 -2.148201382 -1.746144329  1.165627635  0.147844408
##  [366] -1.413054948 -0.171723732  1.096714530 -0.480947845 -1.229087095
##  [371]  0.181497554  0.539881149  0.838847109  0.179337632 -1.554847531
##  [376] -1.217667192 -0.424321084  0.427562898  1.306329086  0.244733907
##  [381] -0.018319974  0.482629490 -0.689041073 -1.667116304 -0.346319356
##  [386]  0.064570777 -1.574264567 -2.207440506 -1.051945280 -1.111121411
##  [391]  0.167807696  0.201134378  0.683058687 -0.664759479 -1.212830635
##  [396]  0.696734970  0.158828102  1.583942327  1.791372021  0.465377020
##  [401] -0.363091916 -1.104795969 -0.164717842  2.522524612  1.169984651
##  [406] -1.372610986  0.081996579  0.398115809 -2.003742795 -1.994834948
##  [411] -0.373964865  0.373148876  3.117540208  1.343549843  0.188719874
##  [416]  2.568912048 -0.371158417 -2.189283626  0.152828339  0.827949663
##  [421] -1.042314055  0.184793628  0.017973245  0.524704647  0.311107670
##  [426] -0.273845822  0.744176584 -0.573672955 -0.861115223 -0.911375372
##  [431] -0.541780258  0.437496710 -0.754191975 -1.203015983 -0.185069528
##  [436]  1.535955730  3.527300695  2.016039842 -1.081232177 -1.809879892
##  [441] -1.498765164 -0.953016973  0.413470579  1.111714419  0.789372683
##  [446]  0.072918144  0.736765955  2.562611901  1.836293966  0.917861686
##  [451]  1.881562860  1.393737833  2.583824241  0.755098410 -1.660852137
##  [456]  0.468562471 -0.998536703 -3.168271897 -1.277768552  0.324566612
##  [461] -0.003663940  0.093115907  0.377134664  0.583357198  1.437986467
##  [466]  1.393354158  2.126828448  1.147804663 -0.078685685  0.865687682
##  [471]  0.753046555  2.047492939  0.437474211 -1.838813403 -0.762289951
##  [476]  0.134168511 -0.885294385 -0.505405161 -0.493840511 -1.057834450
##  [481] -0.559922670 -0.702724120 -1.570278413 -2.560255320 -3.628889625
##  [486] -1.727296752  0.833344561 -0.745084817  0.042634048  0.262861573
##  [491] -0.644089229  0.990125147  1.596641535 -1.130352719 -3.445546100
##  [496] -2.183566181  1.566385317  2.260174538 -0.096599064  1.302802047
##  [501]  1.375947306 -0.589994233  0.288432191  0.544375794 -1.129854081
##  [506] -1.433315135  0.162614327  1.012131173 -1.460079214 -1.238326908
##  [511]  0.088601795 -0.098459313 -0.308925648  0.982919538  0.732791749
##  [516] -1.596193548 -1.249977806  0.217930734 -1.192207980 -1.633116811
##  [521]  0.150441047  0.886872315  0.933184593  1.356049727 -0.083941390
##  [526] -0.875949978  0.246058196  1.556363814  0.949774708 -1.232525770
##  [531] -1.605253476  0.155922434  3.201660617  1.079067401 -1.382909175
##  [536]  0.710039063  3.244282387  0.738267915 -1.093850887  2.111679744
##  [541]  0.797110758 -0.088390595  0.768355994 -0.739508348 -2.358387242
##  [546] -0.958121428  0.869862130 -0.292111128 -0.284069123  0.305448080
##  [551] -0.722874198 -0.131913282 -0.968391621 -0.534947434  0.279385194
##  [556] -0.397542110  1.430931174  2.562702623  1.430667067  1.766922085
##  [561]  0.245960711 -0.105916915 -0.474119380  0.150180051  0.896794352
##  [566] -0.257731455  0.393101117 -0.106567107  0.353601296 -0.478827686
##  [571] -1.222779340  0.262214771 -0.222632164 -1.131732609 -0.970708803
##  [576] -0.539874750  0.493472596  1.299419200  1.091529920  1.332658567
##  [581] -0.102004746 -1.514629252 -2.528029567 -2.649271782 -1.459547395
```

```
##  [586] -0.427625848 -2.313588909 -0.189292576  0.410061001 -1.685680213
##  [591] -0.360502202 -0.626706196 -0.227125464  0.473723536 -0.424210463
##  [596] -1.060918570 -0.077038442  1.095763356 -0.127839352 -0.062912565
##  [601] -0.647808748 -1.674099353  0.115686528  2.221674333  1.121893281
##  [606] -0.094070635  0.556723978  1.796641898  1.481627470  0.253949151
##  [611]  0.029720508  0.938488257  0.182794240 -0.712815478 -0.367382585
##  [616] -0.365942827  1.308113010  0.370827956 -1.479579808 -0.524550493
##  [621] -0.023980918 -1.461644526 -2.494439630  0.065405603  1.123178045
##  [626] -0.082537169 -1.317902444 -2.672175356 -1.243457550  0.803047253
##  [631]  0.978964053 -0.884330249 -1.881034997  0.180990121 -0.674662903
##  [636] -1.080913052 -0.146192267 -0.299167459  0.109919749  0.369838774
##  [641]  0.966974358  0.987377287  1.979792886  1.893587089  1.632274905
##  [646]  0.616170934 -0.775339869 -0.178968760  0.788946563  1.839985928
##  [651]  1.290939797 -0.986242356 -2.947435624 -1.164197338  1.186969239
##  [656]  0.725342792  0.977574232  1.380209038  0.993193394 -0.859979327
##  [661] -0.649999368  1.358084307  0.499835841  1.615429126  2.220823617
##  [666]  0.710627451  1.687220325  0.670563094  1.033032426  3.147858568
##  [671]  2.196639981  0.351092011  0.571860040  1.265579840  1.371072189
##  [676] -0.114854480 -0.030860624  0.087055039 -1.658517366 -0.756610029
##  [681] -0.313550581  1.333344113  2.051852760 -0.073640494  0.283348995
##  [686]  2.052851554  1.736164854  0.285703520 -0.322315369 -0.088310899
##  [691]  0.945630547  0.058956154 -0.957299011  1.633132383  1.911995845
##  [696]  0.809981905  0.617490331  1.067489156 -0.150273061 -0.204059137
##  [701]  2.626407343  1.585802984 -1.219429156 -2.072393841 -0.987930028
##  [706]  0.596315047  1.179359853  1.924825837  0.641511515 -0.293137389
##  [711]  0.303392598  1.114616043  2.412098893  0.760157338  1.447960526
##  [716]  2.700262078  0.979196885  0.879946325  0.518859236  1.463058219
##  [721]  0.455866802 -1.568248115 -1.654978003 -2.263899346 -1.298781147
##  [726] -1.523631010 -1.663673338 -1.598250251  0.219052011  1.565375881
##  [731]  1.760806092  3.158576671  2.849055880  1.324653092 -1.317354617
##  [736] -1.779687889 -0.537544568  0.772979678  1.429869970  0.879636539
##  [741]  2.435904215  0.314641305 -1.488887945 -2.088648571 -1.625725972
##  [746]  0.137394969 -0.609716380  0.224641487  0.309227351 -2.865208164
##  [751] -2.678008599  0.429749106  0.905643654  0.821394116  1.289795575
##  [756]  1.261335696  0.439204503 -0.857015593  0.636601250  1.039166544
##  [761]  0.124514545  3.201932454  2.425935570 -0.360411123 -0.501775508
##  [766]  0.377020552  0.991528524 -0.373010133 -0.544240173  0.253701214
##  [771]  1.762842564 -0.273983127 -1.442255356  0.972266561 -0.030961236
##  [776] -0.121392209  1.622288626  1.803740373  0.940973351  0.439664479
##  [781] -0.226383040 -0.872574919 -0.644593720 -0.259719224 -1.243859860
##  [786] -0.726800754 -0.733622516 -1.988299400 -0.394761974 -1.228273264
##  [791] -2.191344636 -1.295991456 -0.020401517 -0.654810940 -2.077720638
##  [796] -2.467005846 -2.169718385 -0.106832334  0.328733591  1.546735033
##  [801]  2.554551551 -0.950023176 -2.882325141  0.325908702 -0.159328649
##  [806] -2.710888772  0.153559411  0.984237104  0.749527002  0.798860547
##  [811] -1.105532392 -0.944097642 -1.346922720 -1.114978287 -1.566493208
##  [816] -0.765671398  1.089521741 -1.593316337 -1.844139787 -0.802971137
##  [821] -2.185265613  0.008062368  1.434836288  1.605610993  2.130660277
##  [826]  2.665341611  2.750437372  0.699293546 -0.025119238  0.176459764
##  [831]  0.215624528 -0.599601604 -1.011672289 -0.524179899  0.015952599
##  [836]  0.376521080 -0.735631567 -2.562352364 -2.863248089 -2.231739448
##  [841] -2.939089905 -2.060484146  0.676709346  2.258986069  0.954583295
##  [846] -1.062200402 -1.069301245 -1.031455253  0.078538706  0.580977720
##  [851]  1.544680653  1.408998984 -1.837327343 -1.449430905  1.185767925
```

```
##  [856]  2.026594864  0.284800603  0.337341283 -0.998100584 -1.816317270
##  [861]  0.468176654  0.569613984 -1.063358690 -1.576206521 -1.872934144
##  [866] -0.878103289  1.366991243  2.238912373 -0.144539433  0.011698514
##  [871]  1.710708322  0.335272702 -0.614540110 -0.866466534 -0.085092149
##  [876] -0.895966641 -1.953916617  0.117952375  0.387956332  0.440123738
##  [881]  0.570658799 -0.607399658  0.828129165 -0.570141684  0.173142944
##  [886]  1.311126611  0.482020522  0.674719811  1.072667194  0.165265798
##  [891] -1.009057496 -0.187242921 -0.340034275  0.224723499 -1.137168200
##  [896] -3.097778129 -1.044968432  1.416071367  1.284054706 -1.419480378
##  [901] -3.280823120 -1.925712141  0.021813953  1.435488855  1.373501946
##  [906] -0.629175038  0.805533183  2.430420702 -0.013809401 -1.474077934
##  [911]  0.050516920  0.179900014  0.164581809  0.241986413 -0.903460536
##  [916] -1.375153732 -0.629014741  1.009262555  1.337586028 -0.767865282
##  [921] -2.519126212 -0.893155861  0.709908650  0.957061970 -1.130204173
##  [926]  0.099320229  0.800245334 -0.723231839 -0.625653125 -1.207330296
##  [931] -2.223709089 -0.953298595  1.818973997  0.128307162 -1.034103442
##  [936]  0.736003851  2.267940360  1.987313891 -0.266541671 -2.565120220
##  [941] -2.865006572 -0.885745368 -0.486756413 -0.953919499  0.391345164
##  [946] -0.570908838 -0.887154856  0.771115014  0.327591104 -1.357616493
##  [951] -1.303619613 -1.316209842  0.218706792  0.624056268  0.894531136
##  [956]  2.512656912  1.400315610  1.928802999  1.321162345 -0.659519300
##  [961] -1.631974164 -1.843428563 -1.210878923 -1.263139251 -0.691504035
##  [966] -0.599111462  0.640323473  2.248080768  0.921221080 -0.457844939
##  [971]  0.554698931  0.629737289  0.589199387  1.199885902  1.676870839
##  [976]  0.657040078  1.360165083  0.796105283 -1.481220113 -2.019272261
##  [981] -1.948077913 -1.430294428 -2.352498561 -0.048109040  1.757689519
##  [986]  0.921427703  1.937198961 -0.009188981 -1.453195705  0.406044275
##  [991]  1.251633234 -0.414418852 -0.610268521  1.675758652  2.654464485
##  [996]  2.037013920 -0.189169389  2.024726586  3.980263160  0.636753598
```

```
#ARMA(1,1)
ARMAmodel_3_new<- arima.sim(model=list(ar=0.6, ma=0.9), n=1000)
ARMAmodel_3_new
```

```
## Time Series:
## Start = 1
## End = 1000
## Frequency = 1
##    [1]  3.849216538  2.065263403  0.435336213 -1.458578973 -1.541657777
##    [6] -2.670068911 -2.358997206 -0.526474612 -0.753657236 -0.370252032
##   [11] -0.211940584  0.705584050  1.614575014  0.320468195 -0.542136072
##   [16] -0.006704159  1.855650501  2.855615469  2.926865699  3.932652752
##   [21]  3.027143609  1.124068612 -0.414676166 -1.363656056 -3.098298043
##   [26] -2.985945201 -1.927637188 -3.612328127 -2.304669531 -0.106139277
##   [31] -0.618385058 -1.526382701 -0.371441767  0.195813417 -1.270757711
##   [36] -0.272996311  1.639534516  1.720336991  2.055064510  3.559866667
##   [41]  4.251436924  3.461977608  1.838639977 -0.670073458 -3.019099472
##   [46] -3.386308250 -1.680848905 -0.597414932 -0.176872775  0.569103593
##   [51]  0.589480488  0.774706128  2.038185157  2.058371249  0.689551199
##   [56] -1.433585657 -1.880940294 -1.937687884 -3.593108727 -2.582743570
##   [61]  0.308424508  1.467380907 -0.248115119 -3.953417588 -3.277222721
##   [66] -2.238283628 -2.531548710 -0.346354747  1.152901515  1.872968965
##   [71]  2.009743409  1.341414035  1.006265974  1.379193830  1.529793542
##   [76]  1.885670345  0.906667765 -0.045173900 -1.531872782 -2.401708324
##   [81] -0.809691325  0.239414376  1.615196011  0.521510681 -3.581228134
```

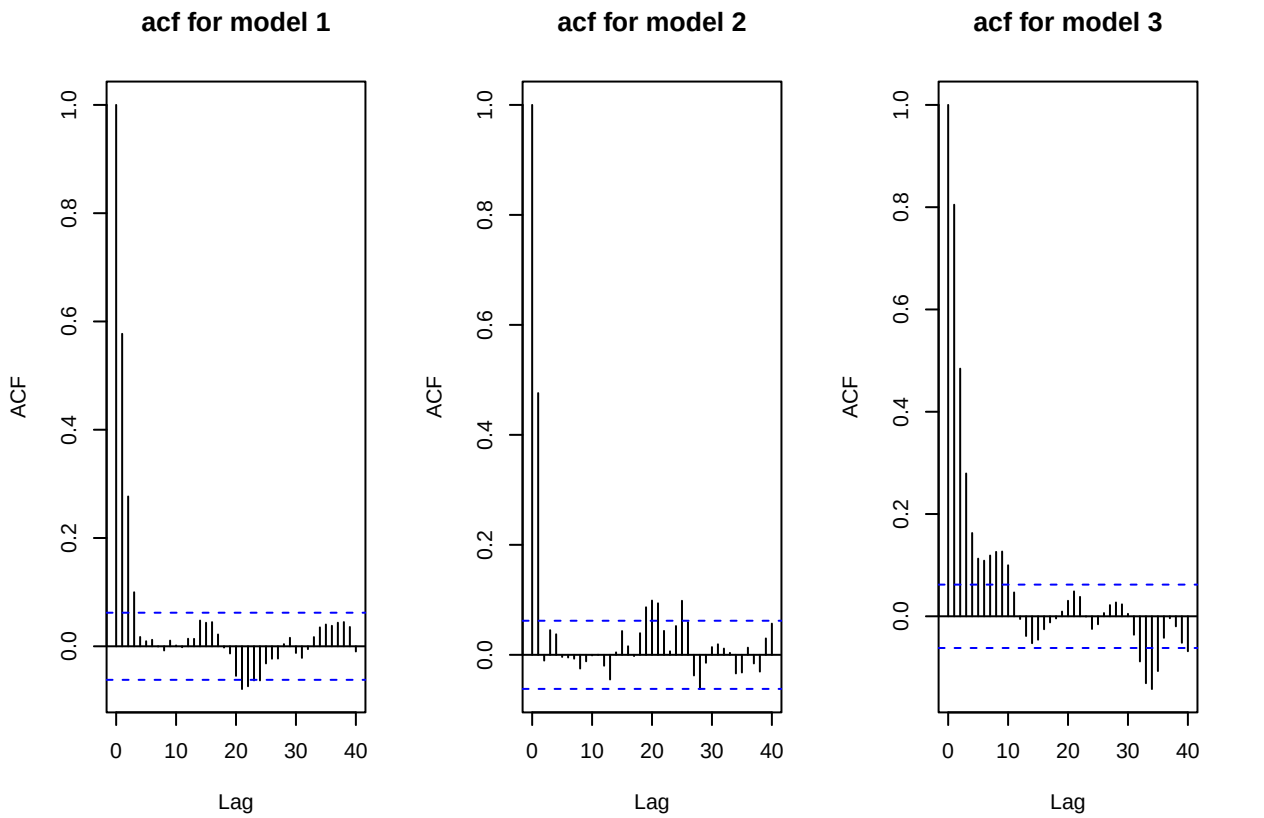
```
##   [86] -3.120649130  1.546663296  2.720892519  2.101732844  1.938683228
##   [91] -0.540803776 -0.313042925  1.589925303  0.091194617 -2.403089608
##   [96] -3.434084262 -1.388128198  0.129952914 -0.198407422 -0.228261680
##  [101]  0.218636234  1.185444043 -0.194656305 -0.521243981  0.672496406
##  [106]  0.982710826  0.589462626 -0.190499954 -0.723788218 -0.319574681
##  [111]  0.818200759  1.814088884  0.665189463 -0.342422165 -0.131674110
##  [116] -0.200959836 -1.019803381 -0.271595401  0.278574373 -0.387856018
##  [121] -1.037836832 -0.166993991  0.641297481 -0.797357461 -0.754717291
##  [126]  1.009734870  0.892066499  0.752147554  2.426044404  3.181938606
##  [131]  3.072749735  1.846766437 -1.088876375 -2.640474045 -1.727666748
##  [136] -0.867867343  0.007411384  1.605476404  2.858560432  2.411488096
##  [141]  1.939473255  3.968542914  2.999000686 -0.388419243 -0.544820368
##  [146]  1.066074213  1.376115286  2.021608366  1.498656518 -0.028477730
##  [151] -0.134844297 -0.718692078 -2.082941615 -3.689363702 -1.891904300
##  [156] -0.262936415 -2.031197080 -2.133378844 -0.241315554  0.628526035
##  [161] -0.412538030 -1.914290741 -1.808873935 -0.209759307 -0.223877448
##  [166]  1.203738614  5.077991954  6.141884364  5.090165450  3.153581453
##  [171] -0.224015061 -2.875754995 -0.584163559  2.465560600  1.296419472
##  [176]  0.753794312  1.310396031 -1.715341500 -4.751430960 -3.890152820
##  [181] -1.596171752  0.431841442  2.272479927  3.251931844  1.324415429
##  [186]  1.321070604  0.734446282 -2.164981456 -3.127283666 -1.749546404
##  [191] -0.920412412 -1.623856738 -0.830103091 -0.171939828  0.003906364
##  [196]  0.978495075 -0.508931259 -2.327265265 -2.467302975 -1.129500321
##  [201] -2.815245413 -4.105443209 -2.947439580 -0.586740418  1.204473857
##  [206]  0.131940887  0.704737514  1.034991705  0.409494814 -0.543190867
##  [211] -0.581053242  0.062989994  0.179162404 -1.729025915 -4.760439619
##  [216] -2.815717883  0.773944576  3.489679987  3.134674460  1.898166163
##  [221]  1.051862476 -0.670687246 -0.948272055 -0.947759720  0.004331805
##  [226]  1.119210769  0.676727986  0.306941459  1.919839415  2.647475465
##  [231]  2.006774833  0.663363192  1.740399983  2.303789644  0.138772161
##  [236]  0.098417122 -0.167399332 -3.138080051 -4.269322660 -1.941725558
##  [241] -0.179856736 -2.337871458 -5.123298696 -6.109955605 -4.548068508
##  [246] -1.246096868  0.926665714  3.169643866  3.357851001  1.327946754
##  [251]  1.412794504 -0.486937745 -2.874249049 -3.083263371 -2.030941705
##  [256] -1.510866999 -2.375786759 -2.190798059 -1.288910697 -1.300748117
##  [261] -3.356377236 -4.742806857 -4.392199794 -2.720154404 -1.305780478
##  [266] -0.743542018  0.610261596  0.280618450 -1.239116777 -1.011307954
##  [271] -1.331942049 -1.947243463  0.765028371  3.741220139  3.541444040
##  [276]  3.151108193  3.062207853  4.037461846  3.062567392  0.432705448
##  [281] -1.403761993 -2.470289892 -2.836777510 -2.627692823 -3.050462180
##  [286] -3.233322575 -4.299873599 -4.543919007 -3.495874666 -2.031476576
##  [291] -0.392907550  2.680554915  3.320975700  1.520918312  1.770703404
##  [296]  3.941415097  3.519579075  0.136139109 -0.907729983  0.923678788
##  [301]  3.010699369  1.952955251  0.783512531  0.780940207  1.460103705
##  [306]  3.242859384  3.137970521  2.074085924  1.318490638  0.020562063
##  [311] -0.060174717 -0.365348406  0.008728750  0.409820868 -1.082225137
##  [316] -1.778639911 -0.746494876  2.088218199  1.525325115  0.548578193
##  [321] -0.560656211 -2.288572791 -2.843728842 -3.305446868 -2.594918729
##  [326] -3.015660718 -3.119953386 -0.692861325  1.934556511  3.969847581
##  [331]  2.483944795 -0.109664970 -0.672583727 -1.220707884 -1.936636186
##  [336] -1.423055771 -0.649723357  0.617829824 -0.240132811 -3.778383512
##  [341] -5.096110957 -2.668506838 -0.894253171 -0.087856890 -0.124787538
##  [346] -0.666064399  0.722025738  0.115534045 -0.007245667  0.987857645
##  [351] -1.243473528 -1.564987236 -0.787580153 -0.303263726  2.073515198
```

```
##  [356]  3.360640392  4.339107141  5.918056692  5.749873196  4.515066736
##  [361]  3.786701916  3.081017370  3.837750121  6.389559435  6.734504653
##  [366]  5.290003225  4.877847100  3.504792038  2.073990413  1.926694234
##  [371]  2.977559520  3.947034140  2.969375387  3.238574886  2.886167744
##  [376]  0.705334865  0.065234516  1.421152380  2.149672891 -0.540000232
##  [381] -2.604176258 -1.899538019  0.650991371  2.555332531  3.399904593
##  [386]  2.827380604  3.177438385  3.016155941 -0.755378002 -4.635847197
##  [391] -4.345513482 -0.676400040  2.083130606  3.956312235  2.813034372
##  [396]  1.776630023  2.275614465  0.208607426 -2.548866482 -3.329123988
##  [401] -2.317591491 -2.580657134 -3.571467345 -6.138717721 -7.727590111
##  [406] -6.937192096 -4.736896725 -2.691195026 -2.039817396 -1.309198149
##  [411] -0.979583206 -1.175954298 -1.323301295 -2.077290436 -2.390585970
##  [416] -1.934316925 -0.714520055  2.457274327  3.797259629  1.690792224
##  [421] -1.590568733 -3.446019740 -2.093368598 -0.378453383 -2.263871043
##  [426] -3.723213850 -2.719111667 -1.878448758 -2.433953177 -4.487843757
##  [431] -5.232554015 -5.604460755 -5.010623673 -4.770870804 -3.489378898
##  [436] -1.009504094 -0.449530081  0.261297331  1.122571639  0.931439082
##  [441] -0.587868391 -1.768070260 -2.691182939 -1.936649421 -1.661281520
##  [446] -2.036363965 -1.262184595 -0.560398486 -0.920157474 -0.290560195
##  [451]  0.739220445  0.599096304  0.165742881 -1.018678225 -1.757780396
##  [456] -1.470987885 -1.855792770 -3.288302245 -5.155436951 -3.354020120
##  [461] -1.067212518 -1.549690511 -0.845183902 -0.063459152  1.606515635
##  [466]  2.749837207  1.390478371  0.063384555 -0.570714516 -0.399878788
##  [471]  0.355352696  0.469802264 -0.272609583 -0.241632121  0.455830367
##  [476]  0.747659384  0.863118907  1.064097052  0.026735053 -0.022113307
##  [481]  0.006045923 -1.383011896 -2.475211827 -4.258458797 -4.103106643
##  [486] -2.215901349 -1.533864279 -0.896937950 -0.998018185 -1.098750885
##  [491] -1.071525030 -2.283224794 -2.056500646 -2.513820655 -2.900530216
##  [496] -0.347203127 -1.121474008 -2.520014405 -1.522977048 -1.059125668
##  [501] -1.270439910 -1.656140673 -1.323306610 -0.849463394 -1.927655169
##  [506] -2.954000971 -2.021956262 -2.151333764 -2.516609711 -1.800219242
##  [511] -0.312369930  1.803656451  2.010640095  0.388484235 -0.936837630
##  [516]  0.485113084  1.792662652  1.180836847 -0.123355772 -0.751074968
##  [521] -1.478289382 -0.517654534  2.103283584  1.211241918  0.618793823
##  [526]  1.798541046  1.985923122  3.002151206  3.339167014  1.248319666
##  [531] -0.985512079 -1.213527362  1.259900663  2.670308744  2.026937454
##  [536]  2.257349789  2.026899330  1.626591594  0.941962296 -0.326683165
##  [541] -1.389348948 -0.418014606  0.311250145 -0.192286198 -0.613790841
##  [546] -0.777572611 -1.007628371 -0.766682910  1.327469466  2.398831807
##  [551]  0.946913477 -0.188685455  0.791879985  1.911208885  2.510563559
##  [556]  2.128482401  0.526001926 -1.270140682 -0.725144396  0.141159782
##  [561]  0.998428270  1.608560220  1.376785367  1.525225198  3.710466484
##  [566]  4.591333521  3.492204147  1.212028424 -0.044699614  0.714414999
##  [571]  0.188805719  0.782544417  1.811726752 -0.289491323 -2.778333517
##  [576] -1.795480101 -0.602615389  0.023953291 -0.425937126 -0.808492232
##  [581]  0.043400535  0.497528555 -0.592769067 -0.835299502  0.203118455
##  [586]  2.043686875  3.456428678  2.362594205  1.686333793  0.696416391
##  [591] -0.680179511 -0.629385435  0.895398381  2.439956207  1.629828283
##  [596]  0.861444954 -1.168049108 -3.272739461 -3.624396278 -3.697210186
##  [601] -0.879715745  0.773270202 -0.996569827 -3.205647349 -3.569571553
##  [606] -1.771372252  0.104770957  0.504299305  0.251168473 -0.102583860
##  [611] -0.061184009  0.518218367  0.342538059  0.371653665  0.208049694
##  [616]  0.271135410  0.656292123  1.900280911  3.153391335  4.512263312
##  [621]  3.959176733  1.531922402 -0.439860636 -0.644362038  1.391737299
```

```
##  [626]  0.768759611 -1.798996857 -0.811513928 -1.320653619 -2.524817963
##  [631] -2.396448312 -2.695011556 -1.522399417 -1.484594047 -4.521524506
##  [636] -5.639747974 -5.063762957 -4.841441797 -2.093123899  1.150717190
##  [641]  1.092147173 -1.452865512 -4.573300993 -5.587827175 -4.493373942
##  [646] -3.323900705 -3.645059243 -3.974686798 -3.598042243 -1.888957130
##  [651]  0.182118010  0.377605522  0.832945002  0.005798867 -1.372145371
##  [656] -0.184753329  0.893850615 -0.157664562 -0.156888779  1.588029241
##  [661]  4.547269979  5.574452888  4.569171134  3.980094581  2.348355304
##  [666] -0.183118719 -0.227449087  1.735053479  2.435540451  2.189991206
##  [671]  3.304346885  2.487880686  0.360449698  0.662474186 -0.452950823
##  [676] -0.203076811  1.730949552  0.994563356  0.337574068 -0.827718127
##  [681] -1.829826122  0.566506472  2.614030395  1.777519818  1.110723208
##  [686]  1.424797682  1.455305697  2.311055908  3.157145601  2.485691911
##  [691]  2.638542247  3.849238828  2.410302774  2.602524135  3.701032499
##  [696]  3.233384447  1.065552328 -0.327651300  1.255406123  0.667975758
##  [701] -1.325335408 -3.556875832 -4.625911311 -3.861938799 -2.440118029
##  [706] -1.617676118 -1.442891899 -1.341196953 -0.376372742  0.921959927
##  [711]  1.120155431  2.060282377  2.005598232  1.769932588  3.144330070
##  [716]  2.678277992  0.984780456  0.219200099 -0.610859529 -0.342345073
##  [721]  0.429707386  0.472349740  1.233682628  0.538162690  1.259808337
##  [726]  3.623779246  1.890411013  1.642954686  2.903321601  1.099934936
##  [731] -1.256819282 -0.675745949  0.388219495 -0.859008249  1.509473705
##  [736]  3.991014578  3.000010355  2.356100987  1.699060820  0.131907970
##  [741] -1.239785914 -0.233286100  0.685957728  0.997034802 -0.395472018
##  [746] -0.493702649 -0.629611009 -2.695626152 -2.499483443 -4.137653868
##  [751] -4.626349131 -1.573962720 -0.912059588 -1.171617321 -1.592050355
##  [756] -1.882140660 -0.926083617 -0.064601912 -3.016701447 -6.329806500
##  [761] -5.981378551 -4.792670871 -2.974099747 -1.970392024 -1.436834758
##  [766] -1.448714303 -1.316722297 -2.171949218 -2.438546688 -1.618851603
##  [771] -1.592386043 -0.133628498  2.065444340  3.243054755  3.646871075
##  [776]  3.138687533  1.261831423  0.111991034  0.423245461  1.005972232
##  [781]  1.318539710  1.720898767  2.001598652  0.707385906 -0.974616273
##  [786] -1.853904358 -0.009822156  2.428417821  3.724753496  2.547347679
##  [791]  1.666691788  1.252839468  1.237960097  1.198752401 -1.633192447
##  [796] -2.231838320 -1.169564276 -1.578223913 -1.212009198  1.591687185
##  [801]  2.474871500  1.105321016  0.349897745 -1.202059695 -2.883545838
##  [806] -4.038149269 -3.815793309 -2.239230891  0.293265927  3.375261182
##  [811]  4.459205464  4.212081815  1.625530665 -1.270383693 -1.769221714
##  [816] -1.160200183 -1.505991873 -0.751408261  2.088903231  2.758227047
##  [821]  2.573271602  1.520006674 -0.280878099 -1.512577269 -0.386328120
##  [826]  1.785456387  2.923546982  2.737893883  0.832797182  0.361127763
##  [831]  1.423693582  2.249260114  0.638795478  0.833794078 -1.966297796
##  [836] -5.701459165 -3.501920753 -0.990931879 -0.961071880 -1.172943180
##  [841]  0.371286631  2.385838020  1.784448235  1.357479669  2.323052176
##  [846]  1.514034106  2.574775499  2.615096834  2.102698596  2.160010170
##  [851]  1.571233493  2.370576214  4.276196788  3.590804512  0.668075123
##  [856]  0.938570344  0.138580667 -2.380996305 -1.514533287 -1.911954398
##  [861] -2.253226781  0.381321220  1.827328287 -0.259496734 -1.478570436
##  [866] -2.150805470 -5.047573710 -3.635688107 -0.732236745 -0.370161265
##  [871] -0.219375839 -0.983502766 -1.199868070  0.047912165  0.157342555
##  [876] -2.562883563 -3.250499972  0.835613446  2.733201576  0.859643741
##  [881] -0.747832763 -2.096516730 -1.956340223 -1.035388184 -1.045702263
##  [886] -1.453613033 -1.302134473 -1.601318819 -0.540362278  0.365410108
##  [891]  0.252305016  0.865698809 -0.504908320 -1.057499706  1.741309218
```

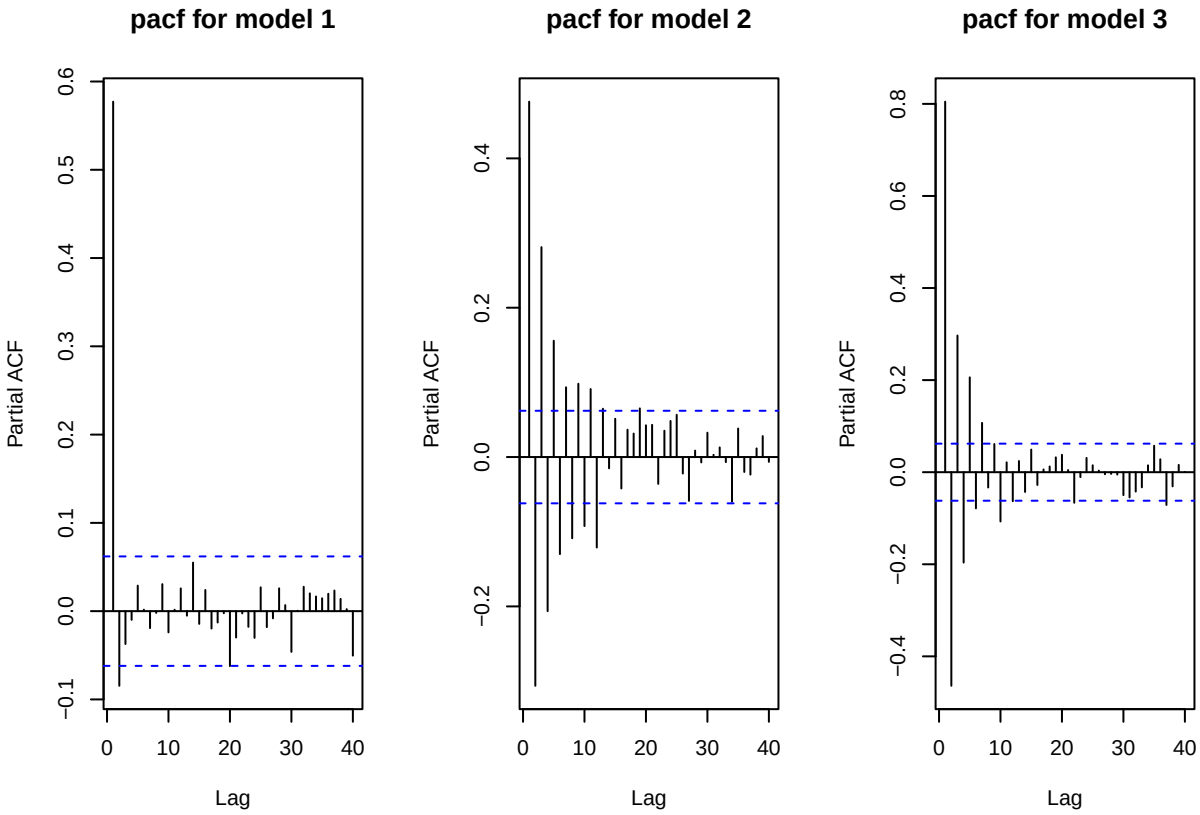
```
##  [896]  2.622223466  0.049696815 -0.721895715 -0.284743512 -1.285654913
##  [901] -0.537888898  0.528748326  1.416398144  3.842554020  4.566635810
##  [906]  2.611882074 -1.936617870 -3.485124732 -2.227199675 -1.464806022
##  [911]  1.298020085  1.434678627 -0.351531273 -0.216928524  0.203137140
##  [916]  0.310898010  1.515893393  1.441778538  0.528438330  0.948093796
##  [921]  0.661254387 -0.540154962 -0.688570665  0.195546203  0.391976542
##  [926] -0.707704243 -1.991161127 -2.718286199 -1.906712457 -1.568140583
##  [931] -1.678375008 -1.816537765 -0.837691298  0.208646021 -0.555396748
##  [936] -0.064621317  0.619863891  0.546510002  0.853263182  2.833759584
##  [941]  5.906107157  6.810469700  4.591874349  1.246220833  0.240681135
##  [946] -1.644777636 -3.091616053 -0.559558089  1.027954885 -0.301758881
##  [951] -0.822902970  0.259331501 -0.624789665 -1.730052599 -2.739507105
##  [956] -1.827781143 -0.471621437 -1.389013803 -1.936898435 -1.377516386
##  [961] -0.712946210  0.567776228  1.443776886  1.236239644 -0.947336849
##  [966] -2.601298836 -3.486828117 -4.589142584 -4.903200683 -4.094573472
##  [971] -1.077245726 -1.006743156 -2.291225849 -2.131057074 -3.276089482
##  [976] -3.122268556 -1.893029990 -0.655116731  0.204527702 -2.978028862
##  [981] -2.760948083 -0.569588189 -1.254735194 -2.115823126 -1.780604770
##  [986]  0.244600078  0.972831041  0.966777047  1.922290026  2.289504058
##  [991]  1.960533276  2.317255994  1.814053740  0.421120798 -0.841506667
##  [996] -1.425442049 -0.310456470  0.406921941  0.758312203 -0.736090599
```

```
par(mfrow=c(1,3))
acf(ARMAmodel_1_new, lag.max = 40, main = "acf for model 1")
acf(ARMAmodel_2_new, lag.max = 40, main = "acf for model 2")
acf(ARMAmodel_3_new, lag.max = 40, main = "acf for model 3")
```




```
par(mfrow=c(1,3))
pacf(ARMAmodel_1_new, lag.max = 40, main = "pacf for model 1")
```

```
pacf(ARMAmodel_2_new, lag.max = 40, main = "pacf for model 2")
pacf(ARMAmodel_3_new, lag.max = 40, main = "pacf for model 3")
```



(c) Look at the ACFs and PACFs. Imagine you had these plots for a data set and you were asked to identify the model, i.e., is it AR, MA or ARMA and the order of each component. Would you be identify them correctly? Explain your answer.

Answer: Model 1 is AR, model 2 is MA, model 3 is ARMA. Model 1 is AR model because ACF will decay exponentially with time, and we found that it is decaying with lags in the ACF of model 1. Model 2 is MA model because pacf has an obvious slow decay. Model 3 is ARMA model because in the PACF initial values dependent on the AR followed by the decay due to the MA part

(d) Compare the ACF and PACF values R computed with the theoretical values you provided for the coefficients. Do they match? Explain your answer.

Answer: The AR model matches with the theoretical value. We set phi=0.6, meaning that the coefficient of AR should be 0.6, we can find that the pacf of lag 1 is 0.6 for model 1. It didn't match with the theoretical value for MA model since we didn't find 0.9 at lag 1. For the ARMA model, ar coefficient at lag 1 in pacf didn't match with the theoretical value (0.6) and ma coefficient at lag 1 in acf didn't match with the thoretical value (0.9).

Q3

Consider the ARIMA model $y_t = 0.7 * y_{t-1} - 0.25 * y_{t-12} + a_t - 0.1 * a_{t-1}$

(a) Identify the model using the notation ARIMA$(p,d,q)(P,D,Q)_s$, i.e., identify the integers p, d, q, P, D, Q, s (if possible) from the equation.

Answer: ARIMA(1,0,1)(1,1,0)

(b) Also from the equation what are the values of the parameters, i.e., model coefficients.

Answer: AR coefficient: 0.7 , MA coefficient: 0.1, SAR coefficient: -0.25

Q4

Plot the ACF and PACF of a seasonal ARIMA$(0,1) \times (1,0)_{12}$ model with $\phi = 0.8$ and $\theta = 0.5$ using R. The 12 after the bracket tells you that $s = 12$, i.e., the seasonal lag is 12, suggesting monthly data whose behavior is repeated every 12 months. You can generate as many observations as you like. Note the Integrated part was omitted. It means the series do not need differencing, therefore $d = D = 0$. Plot ACF and PACF for the simulated data. Comment if the plots are well representing the model you simulated, i.e., would you be able to identify the order of both non-seasonal and seasonal components from the plots? Explain.

```
#install.packages("sarima")
library(sarima)
```

```
## Loading required package: stats4
```

```
##
## Attaching package: 'sarima'
```

```
## The following object is masked from 'package:stats':
##
##     spectrum
```

```
SARIMAmodel_4<- sim_sarima(model=list(ma=0.5,sar=0.8, nseasons=12), n=1000)
SARIMAmodel_4
```

```
##    [1]  2.560442631  2.078847354  1.692164867  0.090356129 -1.094258751
##    [6]  1.306493887  2.782853869  0.747669798  0.917834544 -0.645432084
##   [11] -0.196664945  0.986995903  1.983159261  1.891323285  0.370558470
##   [16] -0.932533785 -2.064942319 -1.142595995  0.634808732 -0.294056759
##   [21]  1.377935163 -0.115571892 -0.094886456  0.589897303  0.869631028
##   [26]  0.392184577  0.303707408  0.183378075 -1.835487608 -1.919014735
##   [31]  0.161435845 -0.168044905  1.223222424 -0.192594342  0.029396777
##   [36]  0.480330261 -0.568181184  0.881315680 -0.594733202 -0.075356475
##   [41] -1.302358574 -2.694716094 -1.756321672 -0.756147864  1.733863393
##   [46]  0.205457188 -0.008312718  1.750967948  0.193293069  0.495514500
##   [51] -2.065861837 -1.534827659 -0.903869498 -3.832599926 -2.765883454
##   [56] -1.228825179  2.378418123  1.100089706  1.519610004  1.995902427
##   [61]  0.539176074  1.793377407 -0.940478058 -0.830245681 -0.723206175
##   [66] -2.751909608 -2.655749171 -3.250053711 -1.231300954 -0.132255403
##   [71]  1.820602276  3.639552715  1.077334718  1.314416732 -2.073216810
##   [76] -2.308760647 -1.075622362 -1.070050387 -0.573835845 -0.602740005
##   [81]  0.169370517  0.840206230  2.113538720  2.044505616  0.393426907
##   [86] -0.636142440 -2.356576895 -3.140513141 -2.687392905 -2.064740741
##   [91] -0.912035954  1.028157110  1.010181659  1.483625844  2.657967310
##   [96]  1.440737052 -0.268543858 -0.363407342 -0.531481457 -2.119196936
##  [101] -2.155589867 -1.303914438  0.551508742  1.950114706  1.517101522
##  [106]  0.578205662  0.373221555  1.238146607  0.244628100 -0.317597128
##  [111]  1.861752119  2.201107590 -1.469244694 -1.834632159 -0.727106954
##  [116]  1.053274673  0.934287871 -1.173233362 -0.850500777  2.006164832
##  [121]  1.692405097  0.679747672  1.025845189  2.017328226  0.312553002
##  [126] -1.495929762 -0.932440573  0.105688194 -1.556077737 -2.169829492
##  [131]  0.638539704  2.913128642  0.648238387  1.206640729  0.596623530
##  [136]  0.545727445 -0.851998531  0.037430421 -0.966686806 -0.860900421
##  [141] -1.078498447 -1.621585394  0.910134422  1.863744107 -0.403327649
```

```
##  [146]  2.014964967  1.001854928  0.736134742 -0.150608269  2.533438753
##  [151]  3.262356312  0.281462997  0.788638860 -1.560406375 -1.438748310
##  [156]  0.555681367 -1.386594405  1.841687719  0.689319215 -0.711174720
##  [161]  2.996079797  3.573477259  1.851461711 -0.992408608  1.530102491
##  [166] -0.848564664 -1.783374913 -1.413926157 -1.362730597  1.760425288
##  [171] -0.539465877 -0.787683508  2.329224434  4.869019773  3.132835232
##  [176]  0.170212983  1.968632293  0.024365742 -2.064614414 -0.391615663
##  [181]  1.305770172  1.147406889 -0.921162871 -0.162419457  1.497030740
##  [186]  2.672367525  1.970873471  2.278499665  2.137575509  2.111743246
##  [191]  0.279233508 -0.406363682  0.768016570  1.663469827 -1.441087080
##  [196]  1.041312853  4.497686844  3.945379827  1.974341492  1.642418849
##  [201]  1.461559780  1.514024213 -1.630770553 -1.885028169  0.042984773
##  [206]  0.756162027 -0.563780355  0.358024014  2.766300359  4.794669148
##  [211]  1.187373827  1.030951743  0.788601497  2.529682948  0.401965505
##  [216]  0.978595038  1.067489366  2.191372427  0.276152226 -1.354211410
##  [221]  2.046263105  4.528328757  0.998149684 -0.550390986 -1.582776295
##  [226]  1.972145305  0.386548125 -0.271830646 -1.485278827 -0.547466992
##  [231] -0.366161538 -2.254114169  0.899675307  3.901284194  0.374300249
##  [236]  0.811710301 -1.276984986 -0.045637669 -0.532230521 -0.872085532
##  [241] -0.872837116 -0.869391577 -1.014551802  0.250653954  2.055693569
##  [246]  3.801123216  1.405795422 -0.506884084 -1.635237805 -0.712899497
##  [251] -0.957352565 -0.289140438 -0.510247728 -0.083841682  0.210746065
##  [256]  0.208123842  2.616578962  3.028138700  0.066320740 -1.314479740
##  [261] -1.332682875  0.728103703 -0.527564740  2.428424652 -0.315893636
##  [266] -0.728395431  0.578673765 -0.160627921  1.097199424  1.623503270
##  [271] -0.743269269  0.178527964  0.269220824  1.194557066  0.906303200
##  [276]  2.643840285  1.520380575  1.343968636  1.653178465  0.242216477
##  [281] -0.597041768  1.386163139 -1.279493776 -0.075568545  1.937650480
##  [286]  3.187876958  3.048830356  2.633989232  2.619721974  0.528350343
##  [291]  1.108911465  0.129581668 -0.944750246  1.097305038 -0.896919162
##  [296] -1.236142847  1.422950608  2.558181929  2.414480826  3.641474240
##  [301]  2.146957009  0.958217869  0.865255604 -0.386281828 -1.099609645
##  [306] -0.044674044 -2.307938417 -1.970794190  0.669520824  0.738866266
##  [311]  2.885716328  3.589846953  3.130305826  3.061759603  2.956673254
##  [316] -0.003188698 -1.914365087 -0.583349665 -1.875987710 -1.669581623
##  [321]  2.435463568  4.022687064  2.185461073  3.435071994  2.037353081
##  [326]  0.251716521  0.355686819 -1.184676685 -1.575593250  0.145276634
##  [331] -1.340533819 -1.474064637  2.839395820  4.488175417  2.002688482
##  [336]  2.429832359  1.321089101 -0.393186895  0.960375822 -0.083993945
##  [341] -0.684895822  1.407947492 -0.693808580 -1.064820108  2.432383869
##  [346]  5.090343043  2.598175140  2.746213561  2.191998425 -1.870598384
##  [351] -0.579950353  0.902576233 -0.362970475  1.655480172  0.406415872
##  [356] -0.037146274  0.621434461  3.555561802  0.416450452  1.913413453
##  [361]  0.560151151 -1.716542653  0.090205339  2.371131543  1.520635126
##  [366]  0.397304875  0.363401135  1.569056553  0.023008117  2.065898907
##  [371]  0.535166371  0.472209484 -0.598943290 -2.559418096  0.046877281
##  [376]  2.583605496  2.989095910  0.758442770  1.072836657  2.144325995
##  [381]  1.918920364  3.350064931 -0.928525304  0.097817682  0.771523397
##  [386] -0.928288808  0.733876023  2.011508304  1.790983401  1.261890577
##  [391]  0.744872219  2.076429147  1.713010564  3.544023968  1.292546145
##  [396]  1.086611381  2.721307072  0.386732821 -0.553385912  1.131053311
##  [401]  1.171427460  1.506520899  3.117874344  2.723894512  2.837839024
##  [406]  4.485707873  2.064836454  2.281248010  3.456472544  1.009307088
##  [411] -1.003302999  0.056203981  0.629474143  1.560778111  3.080163724
```

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##  [416]  3.211621102  1.748157987  3.497666893  2.652426257  1.453648758
##  [421]  0.892585781 -1.638283398 -1.489620810  1.277717490  1.227682521
##  [426] -0.801619007  2.776680507  3.616227743  3.244190168  4.933537763
##  [431]  3.973562311  0.941329100  0.318566390 -2.030781130 -1.040056117
##  [436]  0.675589482  2.701239453  0.618277913  2.593341582  3.586732937
##  [441]  2.861599634  4.385557580  3.340472301  2.155367945  2.095630306
##  [446] -0.610400572 -1.882353905  1.833653320  2.661588808  2.275803262
##  [451]  3.151755451  2.330738949  2.182517497  5.462927749  3.779937866
##  [456]  1.490095545  0.871768527 -2.735970179 -1.641827099  3.597170546
##  [461]  3.582670750  1.355864577  2.775335712  1.676697808  0.854802169
##  [466]  3.822832667  2.401703740  1.633460769  0.868391749 -2.250601385
##  [471] -1.347414039  4.232732891  4.094443468  0.934467634  1.870530748
##  [476]  0.203709949 -1.427093468  1.688509843  1.412542488  2.005432478
##  [481]  1.134392661 -1.340852943 -2.232895897  2.486065895  4.021392806
##  [486] -0.436467235  1.107601464  0.909439532 -1.346436658  0.396713641
##  [491]  0.058036890  0.846671775  0.098714706 -0.518502642 -0.583644227
##  [496]  2.303736580  2.882824353  0.453990049  1.655724207  1.336683898
##  [501] -1.722935464 -2.999899299 -0.309279709  2.300180499  0.092576832
##  [506] -0.256322583  0.461754629  1.414391901  1.920221620 -0.377916445
##  [511] -0.021106105 -0.244558751 -1.927800437 -2.309523838 -0.248741233
##  [516]  0.867807162  0.122241333 -0.427820016  0.484681772  1.699315486
##  [521]  1.574260564 -0.788633549 -0.493133627 -0.360513761 -3.193770510
##  [526] -3.139789598 -1.497634065  0.481210663 -0.289409923  0.388446088
##  [531]  0.265884597  0.163738534  0.797142345 -1.089314303  0.027078554
##  [536] -2.086028619 -3.506034192 -3.364526048 -2.721716358  0.185725371
##  [541] -1.987093112 -1.622237347  0.244753369  0.756639053  2.489885277
##  [546]  0.988125627  0.630513095 -1.733363645 -3.025535113 -1.236481992
##  [551] -1.519678053 -0.165758699 -3.402328461 -2.320839755  0.105086993
##  [556]  0.458935897 -0.725048536 -0.993529084 -0.777015729 -1.361981338
##  [561] -4.623258164 -1.897018188 -0.621280294  0.735317693  0.018415963
##  [566] -0.756192297  1.988517893  3.407686517  0.143103961 -2.519586565
##  [571] -1.422780431 -1.160066004 -3.435649595 -1.164935007 -1.962637470
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##  [581] -1.135661813 -3.287936516 -0.455564532 -0.738518583 -2.596876608
##  [586] -0.632937392  0.345287158 -1.169497238 -2.181936378 -1.455192882
##  [591] -1.041435938  1.721378327 -2.914190263 -4.120938485 -0.041770952
##  [596] -1.952802440 -2.671025005 -1.327671043  1.026526538 -0.086124760
##  [601] -1.805895861 -0.992795845  0.008823899  1.867105917 -1.592353642
##  [606] -2.423470788 -0.824955380 -0.692838622 -2.003595778 -1.754912106
##  [611] -1.374676885 -0.471275552  0.564480153 -0.946217152 -3.563458636
##  [616]  0.368342451  0.642202560 -2.462451315 -3.352639087 -2.529369040
##  [621] -2.758293131 -1.660021982 -0.627326813 -1.254996133  0.212826654
##  [626] -0.472145323 -3.328116795  0.258547368  0.833866148 -0.403110040
##  [631] -1.267156902 -2.489502227 -5.820745931 -3.183663562 -2.725169601
##  [636] -2.782613532 -2.076871805 -0.352937793 -2.755986241  0.020083400
##  [641] -0.756923252 -2.546511386 -0.625708762 -1.389671151 -4.587999776
##  [646] -1.910665846 -0.716360059 -1.526010789 -0.159207626  1.707617212
##  [651] -1.715835868  0.872757665 -1.093297682 -1.774066097 -0.499912856
##  [656] -0.056608837 -0.989908101 -2.730689737 -0.169638356 -0.936347730
##  [661] -1.257647906  1.563124334 -1.638139750  2.303696268 -0.209075502
##  [666] -2.354410619 -1.258429344  0.129935780  0.917778528  0.827075198
##  [671]  1.083521514 -0.166953842 -1.100462191  1.382036223 -0.479352876
##  [676]  1.748068023  1.096595812 -1.691194977 -1.603542916 -0.768685083
##  [681]  0.269733931  1.273653940 -0.394288713 -1.745970193  0.669343524
```

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##  [686]  1.831165340  0.118736584  2.123620442  1.915499210 -0.493936185
##  [691]  0.087912889 -0.481450660 -0.030363722  0.443833778 -0.659373588
##  [696] -2.191481526  0.922748701  0.193842838 -1.326921985  1.771508917
##  [701]  0.387063598 -1.807876870 -1.495971546 -0.926619222 -0.320277179
##  [706]  0.223753184  0.360781156 -2.438528937  1.213369955  0.704622447
##  [711]  0.020233817  1.176316373  0.851169976 -0.301253241 -0.715259346
##  [716] -0.477437004 -0.627623770 -0.133072643  1.748804717 -1.844980814
##  [721]  0.273992822 -0.036732294 -1.172785474  0.229418293 -0.514177858
##  [726] -1.699434345 -0.888460627 -1.617652963 -0.533389736  0.796459178
##  [731]  1.323923864 -2.122620334 -0.857650003 -0.177698680  0.204486412
##  [736]  1.015018173  0.364147342 -0.929278475 -0.328548076 -1.187995475
##  [741]  0.009544491  0.550491038  2.329432369 -0.364968416 -1.668854846
##  [746] -0.568998146  0.423925034  0.589123404  1.036124348  0.145243975
##  [751]  1.905675576 -0.707125632 -0.504054118  1.174512853  2.363530914
##  [756] -0.297972230 -0.009764418 -0.714714480  0.647794404  1.584837886
##  [761]  0.998822006  0.834625061  1.597809561 -1.050058104 -0.757467099
##  [766]  1.545455966  2.332503560 -1.001838746  1.455571587 -0.388807736
##  [771] -0.377421397  0.218352222 -0.367724368  1.108961117  1.757120584
##  [776] -2.613825692 -0.441754127  2.503971151  2.467950846 -0.623102700
##  [781]  0.622391215 -0.800736858  0.248884626 -1.386233329 -1.243319988
##  [786] -0.407416485 -1.123933266 -1.319815102  0.779338912  1.214556046
##  [791]  1.770166870  2.650062395  1.549314092 -2.015872843 -0.102125054
##  [796] -1.497383043 -0.834339686 -0.707856525 -0.941585052 -0.052638686
##  [801]  0.566551602 -0.867965175  2.411217302  1.849687666  0.583582825
##  [806] -0.410379631 -1.458436483 -2.612845826 -0.826924423 -0.640265813
##  [811] -1.863567745 -1.974684403  1.170183547 -0.084736252  3.537533871
##  [816]  1.592323957  1.251653097 -1.955991581 -0.548582393  0.343437686
##  [821] -0.415903260 -1.544840175 -1.464918154 -1.405033792  1.502134404
##  [826]  0.364158199  1.799314019 -0.675604752  0.571915870 -0.085064123
##  [831] -0.392211115  0.178792236 -0.994812813 -1.367438178 -1.685686337
##  [836] -2.177603007  2.300367974  2.611337475  2.255820672 -0.686139094
##  [841] -0.107651814 -2.711739594 -1.126268264  1.174498291 -0.075615798
##  [846] -1.820374532 -2.279682406 -2.716869706 -0.759796897  0.427773753
##  [851]  1.685651460 -2.204849992 -2.996022712 -4.657714668 -2.386791422
##  [856]  0.272360820 -1.595025063 -1.717498648 -3.058381356 -2.987399281
##  [861]  0.131518718 -0.552753480 -1.101124251 -3.925729978 -0.166800048
##  [866] -3.748247040 -1.478610335  1.442521874 -2.375574591 -3.636515242
##  [871] -3.800737022 -2.742094931 -0.019896599  0.171980881 -0.813488996
##  [876] -3.038627933 -0.855745836 -3.336222008 -0.528908021  0.346974538
##  [881] -1.641087813 -2.059101671 -4.235456915 -4.465898598 -0.102657408
##  [886]  1.478380617 -1.522771287 -4.392727249 -2.246140469 -4.950798918
##  [891] -1.059360381  0.087428647 -1.004109722 -1.946856548 -2.295966905
##  [896] -2.623740863  0.410623585  0.048588871 -1.657963543 -2.402519242
##  [901] -1.900383584 -5.287843319 -1.249306881  0.332397026 -0.910639467
##  [906] -3.182742891 -2.928325519 -0.681569403  0.714864340  0.785991970
##  [911] -1.628962534 -2.445414691 -1.356100658 -2.719050412 -0.769815651
##  [916]  0.368155395  0.352219167 -0.038939066 -2.849290262 -1.979064065
##  [921] -1.235964667  0.393067025 -1.457672420 -3.261602132 -1.667685751
##  [926] -3.302805315 -2.011633118 -0.052973354  1.316964435  1.306858497
##  [931] -2.137088494 -2.565509275 -3.829166400 -0.748694975 -0.941884154
##  [936] -3.631238119 -0.735726613 -3.055533306 -2.497477499  0.289429791
##  [941] -0.429534727  2.069013415 -2.561168670 -2.462751625 -2.345232175
##  [946]  0.140598770  0.201175210 -2.778801078 -0.053936729 -2.274324774
##  [951] -3.058389947  0.548830964  1.194163368  1.795828527 -2.529669080
```
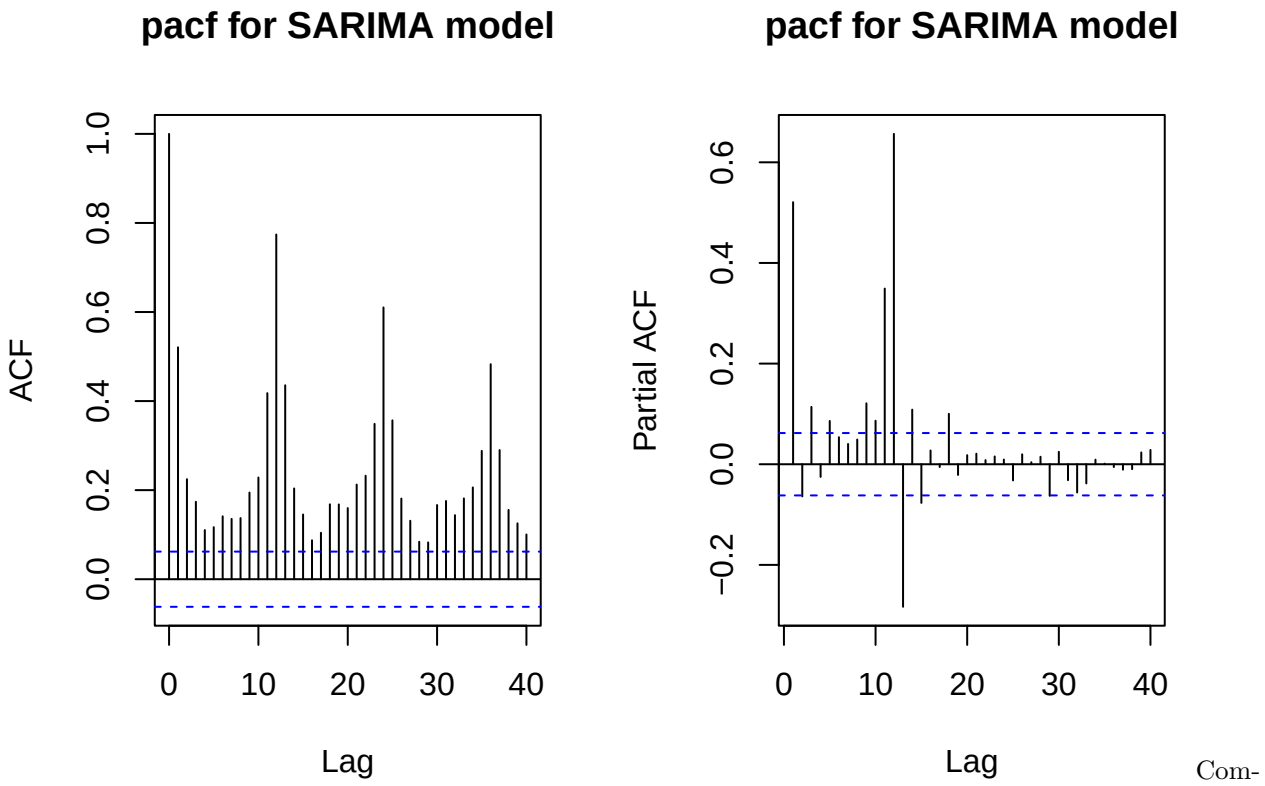

```
##  [956] -1.950041500 -1.328250332 -0.570411636 -0.700923568 -0.696033052
##  [961]  0.849242771 -2.525097911 -1.462290475  1.741829097  1.816892141
##  [966]  3.454873644 -2.934653057 -2.031958792 -1.510724465 -0.113490390
##  [971] -1.186667056 -2.060309641 -0.131409407 -1.428959316 -2.215650251
##  [976] -1.524952527  0.503522697  2.433127805 -2.791140206 -1.267172852
##  [981] -2.653776561 -0.613931954 -0.912994139  0.479776726  2.012353571
##  [986] -1.102860765 -2.647870252 -1.636615509 -0.240103651  0.217914877
##  [991] -2.976164451 -1.840268531 -2.161327106 -0.215674936  0.189969036
##  [996]  0.511867041  0.708756600 -1.499782245 -2.597800679 -3.014224965
```

```
par(mfrow=c(1,2))
acf(SARIMAmodel_4, lag.max = 40, main = "pacf for SARIMA model")
pacf(SARIMAmodel_4, lag.max = 40, main = "pacf for SARIMA model")
```



Comment if the plots are well representing the model you simulated, i.e., would you be able to identify the order of both non-seasonal and seasonal components from the plots? Explain.

Answer: From the non-seasonal part of the acf plot, it cuts off which is a MA process, and q=1. From the non-seasonal part of the pacf plot, it also tails off which shows a MA process, and p=2. From the seasonal part of the acf plot, there are multiple positive spikes at seasonal lags (lagg 12, 24, 36), showing that it is a SAR process and P=1. From the seasonal part of pacf plot, there is a single spike which also reflects a SAR process and Q=0.