In [33]:
```
import numpy as np
import matplotlib.pyplot as plt
from statsmodels.graphics.tsaplots import plot_acf, plot_pacf
def ar_model(p, phi_0, n, burnin=100):
    y = np.zeros(n + burnin)
    for t in range(p, n + burnin):
        y[t] = c + np.dot(phi, y[t-p:t][::-1]) + np.random.normal()

    return y[burnin:]
```

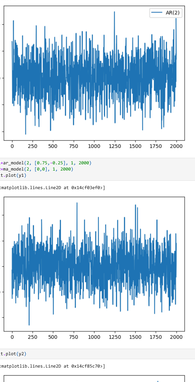
In [42]:
```
def ma_model(q, theta, c, n, burnin=100):
    y = np.zeros(n + burnin)
    e = np.random.normal(size=n + burnin)
    for t in range(q, n + burnin):
        y[t] = c + e[t] + np.dot(theta, e[t-q:t][::-1])
    return y[burnin:]
```

In [21]:
```
np.random.seed(101)
arparams=np.array([0.75,-0.25])
maparams=np.array([0,0])
ar=np.r_[1,-arparams]
ma=np.r_[1,maparams]
print(ar)
print(ma)
```

```
[ 1.    -0.75  0.25]
[1 0 0]
```

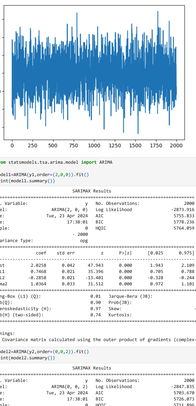
In [24]:
```
import pandas as pd
from statsmodels.tsa.arima_process import arma_generate_sample

y=arma_generate_sample(ar,ma,2000)
df=pd.DataFrame(y,columns=['AR(2) '])
df.plot()
```

Out[24]:
```
<Axes: >
```



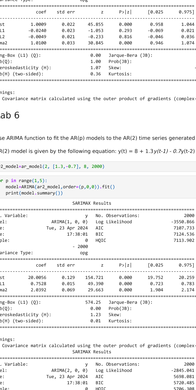
In [25]:
```
y1=ar_model(2, [0.75,-0.25], 1, 2000)
y2=ma_model(2, [0,0], 1, 2000)
plt.plot(y1)
```

Out[25]:
```
[<matplotlib.lines.Line2D at 0x14cf03e49c>]
```



In [26]:
```
plt.plot(y2)
```

Out[26]:
```
[<matplotlib.lines.Line2D at 0x14cf05c79c>]
```



In [27]:
```
from statsmodels.tsa.arima.model import ARIMA

model1=ARIMA(y1,order=(2,0,0)).fit()
print(model1.summary())
```

```
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(2, 0, 0)   Log Likelihood               -2873.916
Date:                Tue, 23 Apr 2024   AIC                           5755.833
Time:                        17:38:01   BIC                           5778.236
Sample:                             0   HQIC                          5764.059
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          2.0258      0.042     47.943      0.000       1.943       2.109
ar.L1          0.7668      0.021     35.396      0.000       0.725       0.809
ar.L2         -0.2858      0.021    -13.601      0.000      -0.327      -0.245
sigma2         1.0564      0.033     31.512      0.000       0.991       1.122
===================================================================================
Ljung-Box (L1) (Q):                   0.01   Jarque-Bera (JB):                 0.06
Prob(Q):                              0.90   Prob(JB):                         0.97
Heteroskedasticity (H):               0.98   Skew:                             0.01
Prob(H) (two-sided):                  0.74   Kurtosis:                         2.99
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

In [28]:
```
model2=ARIMA(y2,order=(0,0,2)).fit()
print(model2.summary())
```

```
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(0, 0, 2)   Log Likelihood               -2847.835
Date:                Tue, 23 Apr 2024   AIC                           5703.670
Time:                        17:38:01   BIC                           5726.073
Sample:                             0   HQIC                          5711.896
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          1.0009      0.022     45.855      0.000       0.958       1.044
ma.L1          0.0240      0.023      1.053      0.292      -0.021       0.069
ma.L2         -0.0843      0.021     -4.115      0.000      -0.124      -0.044
sigma2         1.0100      0.033     30.845      0.000       0.946       1.074
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):                 0.76
Prob(Q):                              1.00   Prob(JB):                         0.68
Heteroskedasticity (H):               1.07   Skew:                            -0.00
Prob(H) (two-sided):                  0.26   Kurtosis:                         2.98
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

Lab 6

Use ARIMA function to fit the AR(p) models to the AR(2) time series generated during the previous lab.

AR(2) model is given by the following equation: y(t) = 8 + 1.3.y(t-1) - 0.7y(t-2) + e(t)

In [29]:
```
ar2_model=ar_model(2, [1.3,-0.7], 8, 2000)
```

In [30]:
```
for p in range(1,5):
    model=ARIMA(ar2_model,order=(p,0,0)).fit()
    print(model.summary())
```

```
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(1, 0, 0)   Log Likelihood               -7550.866
Date:                Tue, 23 Apr 2024   AIC                           15107.733
Time:                        17:38:01   BIC                           15124.536
Sample:                             0   HQIC                          15113.962
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         20.0056      0.129    154.721      0.000      19.752      20.259
ar.L1          0.7118      0.015     49.390      0.000       0.683       0.740
sigma2         2.4392      0.069     35.663      0.000       2.305       2.573
===================================================================================
Ljung-Box (L1) (Q):                   0.25   Jarque-Bera (JB):                 5.30
Prob(Q):                              0.62   Prob(JB):                         0.07
Heteroskedasticity (H):               1.23   Skew:                             0.04
Prob(H) (two-sided):                  0.01   Kurtosis:                         2.76
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(2, 0, 0)   Log Likelihood               -2845.041
Date:                Tue, 23 Apr 2024   AIC                           5698.083
Time:                        17:38:01   BIC                           5720.485
Sample:                             0   HQIC                          5706.308
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         20.0024      0.053    376.315      0.000      19.898      20.107
ar.L1          1.2896      0.016     80.299      0.000       1.258       1.321
ar.L2         -0.7121      0.016    -44.779      0.000      -0.743      -0.681
sigma2         1.0060      0.031     32.174      0.000       0.945       1.067
===================================================================================
Ljung-Box (L1) (Q):                   1.02   Jarque-Bera (JB):                 1.23
Prob(Q):                              0.31   Prob(JB):                         0.54
Heteroskedasticity (H):               1.13   Skew:                            -0.04
Prob(H) (two-sided):                  0.12   Kurtosis:                         3.08
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(3, 0, 0)   Log Likelihood               -2844.079
Date:                Tue, 23 Apr 2024   AIC                           5698.157
Time:                        17:38:01   BIC                           5726.162
Sample:                             0   HQIC                          5708.440
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         20.0024      0.055    364.813      0.000      19.895      20.110
ar.L1          1.3117      0.023     57.843      0.000       1.267       1.356
ar.L2         -0.7521      0.033    -22.698      0.000      -0.817      -0.687
ar.L3          0.0318      0.023      1.360      0.174      -0.014       0.078
sigma2         1.0051      0.031     32.169      0.000       0.944       1.066
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):                 1.24
Prob(Q):                              1.00   Prob(JB):                         0.54
Heteroskedasticity (H):               1.12   Skew:                            -0.04
Prob(H) (two-sided):                  0.13   Kurtosis:                         3.08
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(4, 0, 0)   Log Likelihood               -2843.521
Date:                Tue, 23 Apr 2024   AIC                           5697.041
Time:                        17:38:01   BIC                           5730.647
Sample:                             0   HQIC                          5709.447
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         20.0024      0.056    360.253      0.000      19.894      20.111
ar.L1          1.3113      0.023     57.872      0.000       1.267       1.356
ar.L2         -0.7427      0.037    -20.208      0.000      -0.815      -0.671
ar.L3          0.0165      0.037      0.391      0.696      -0.058       0.087
ar.L4          0.0126      0.023      0.555      0.579      -0.032       0.057
sigma2         1.0049      0.031     32.169      0.000       0.944       1.066
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):                 1.21
Prob(Q):                              0.99   Prob(JB):                         0.55
Heteroskedasticity (H):               1.13   Skew:                            -0.04
Prob(H) (two-sided):                  0.13   Kurtosis:                         3.08
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
```

Repeating the analogous calculations for the MA(2) series generated during the previous lab.

MA(2) model is given by the following equation: y(t) = e(t) - e(t-1) + 0.8*e(t-2)

In [31]:
```
ma2_model=ma_model(2, [-1, 0.8], 0, 2000)
```

In [32]:
```
for q in range(1,5):
    model=ARIMA(ma2_model,order=(0,0,q)).fit()
    print(model.summary())
```

```
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(0, 0, 1)   Log Likelihood               -1288.734
Date:                Tue, 23 Apr 2024   AIC                           2583.468
Time:                        17:38:02   BIC                           2600.270
Sample:                             0   HQIC                          2589.697
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.0088      0.013      0.690      0.490      -0.016       0.034
ma.L1         -0.5078      0.019    -29.414      0.000      -0.543      -0.474
sigma2         1.5694      0.051     30.798      0.000       1.469       1.669
===================================================================================
Ljung-Box (L1) (Q):                 144.81   Jarque-Bera (JB):                 1.22
Prob(Q):                              0.00   Prob(JB):                         0.54
Heteroskedasticity (H):               0.98   Skew:                             0.03
Prob(H) (two-sided):                  0.74   Kurtosis:                         2.90
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(0, 0, 2)   Log Likelihood               -2791.560
Date:                Tue, 23 Apr 2024   AIC                           5591.119
Time:                        17:38:02   BIC                           5613.524
Sample:                             0   HQIC                          5599.345
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.0088      0.017      0.518      0.618      -0.025       0.043
ma.L1         -0.9929      0.014    -73.021      0.000      -1.020      -0.966
ma.L2          0.7828      0.014     56.717      0.000       0.755       0.809
sigma2         0.9537      0.030     32.287      0.000       0.896       1.012
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):                 1.34
Prob(Q):                              1.00   Prob(JB):                         0.51
Heteroskedasticity (H):               1.00   Skew:                             0.01
Prob(H) (two-sided):                  1.00   Kurtosis:                         3.09
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(0, 0, 3)   Log Likelihood               -2791.560
Date:                Tue, 23 Apr 2024   AIC                           5593.119
Time:                        17:38:02   BIC                           5621.124
Sample:                             0   HQIC                          5603.402
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.0088      0.017      0.518      0.618      -0.025       0.043
ma.L1         -0.9928      0.022    -45.116      0.000      -1.036      -0.950
ma.L2          0.7818      0.025     30.817      0.000       0.732       0.832
ma.L3          0.0002      0.022      0.011      0.992      -0.043       0.043
sigma2         0.9537      0.030     32.224      0.000       0.896       1.012
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):                 1.34
Prob(Q):                              1.00   Prob(JB):                         0.51
Heteroskedasticity (H):               1.00   Skew:                             0.01
Prob(H) (two-sided):                  1.00   Kurtosis:                         3.09
===================================================================================

Warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).
                               SARIMAX Results                                
==============================================================================
Dep. Variable:                      y   No. Observations:                 2000
Model:                 ARIMA(0, 0, 4)   Log Likelihood               -2791.131
Date:                Tue, 23 Apr 2024   AIC                           5594.262
Time:                        17:38:02   BIC                           5627.868
Sample:                             0   HQIC                          5606.665
                                - 2000                                         
Covariance Type:                  opg                                         
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          0.0088      0.018      0.500      0.617      -0.026       0.043
ma.L1         -0.9941      0.022    -45.116      0.000      -1.037      -0.951
ma.L2          0.7993      0.031     25.496      0.000       0.738       0.861
ma.L3         -0.0217      0.031     -0.691      0.490      -0.083       0.040
ma.L4          0.0218      0.022      0.946      0.344      -0.022       0.066
sigma2         0.9532      0.030     32.224      0.000       0.895       1.011
===================================================================================
Ljung-Box (L1) (Q):                   0.00   Jarque-Bera (JB):                 1.45
Prob(Q):                              0.97   Prob(JB):                         0.48
Heteroskedasticity (H):               1.00   Skew:                             0.05
Prob(H) (two-sided):                  0.98   Kurtosis:                         3.10
===================================================================================
```

warnings:
[1] Covariance matrix calculated using the outer product of gradients (complex-step).