R09546042_TSA_HW_02

October 10, 2021

0.0.1 import used library

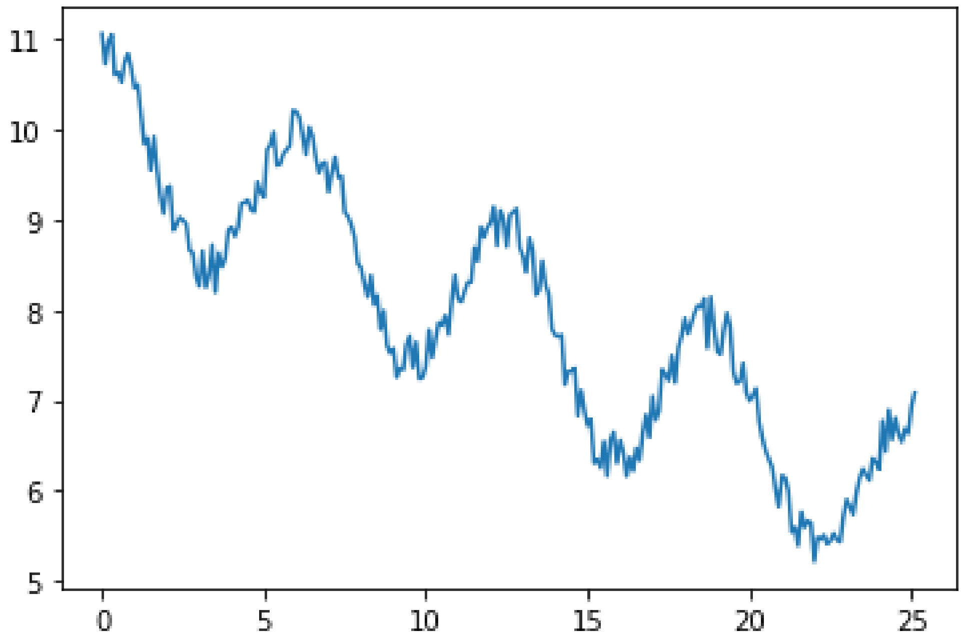
[1]:
```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
from sklearn.linear_model import LinearRegression
from statsmodels.tsa.holtwinters import ExponentialSmoothing as HWES
```

1 Q1

1.1 a. Explain how you design the disturbance.

1.1.1 Use cos() for changing time-series, -x/6 for dwindling trend, 10 as label, and normal distribution(-0.3~0.3) for noise.

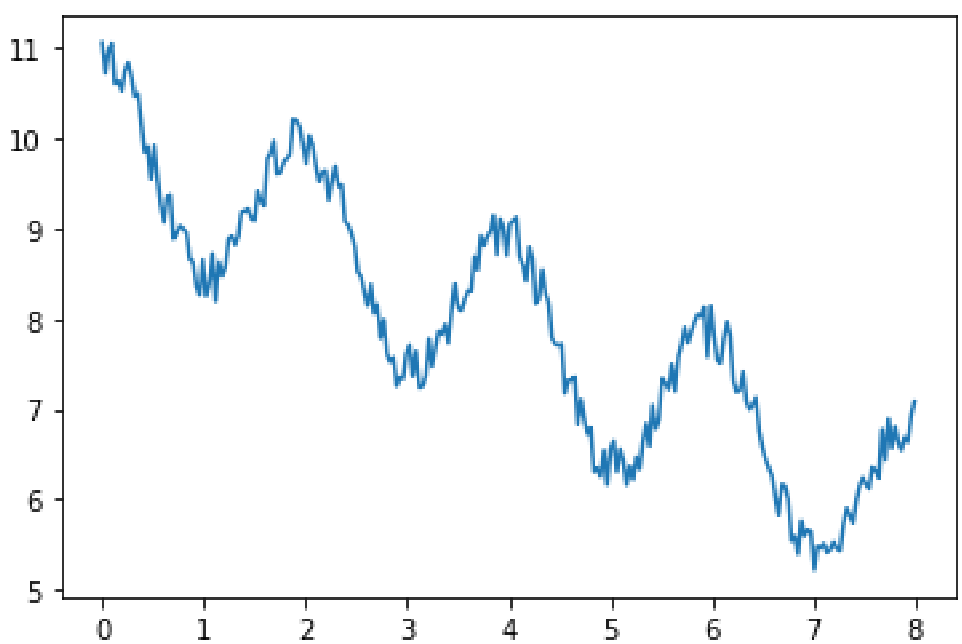
[2]:
```
x = np.arange(0,8*np.pi,0.1)
y = 10+np.cos(x)-x/6

# generate noise
y_noise = []

for i in y:
    n = 0.3
    noise = np.random.uniform(-n,n)
    y_noise.append(i + noise)

plt.plot(x,y_noise)
plt.show()
```



1.2 b. Identify the number of periods in a season and then deseasonalize the series.

1.2.1 Change x scale into #pi, making observation easier

[3]:
```
plt.plot(x/np.pi,y_noise)
plt.show()
```

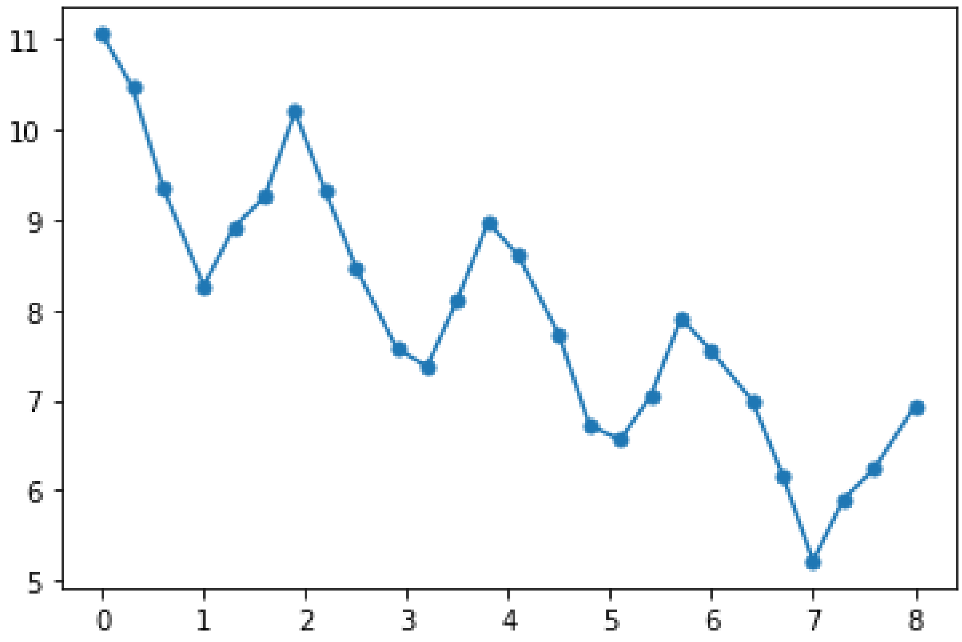


1.2.2 As the creator of this time-series, we know that its period is 3.14(by cos()), which means there are 3 interger data points in one period.

1.2.3 Leading us to assume period roughly close to 3.

[4]:
```
df_original_series = pd.DataFrame({
    'period': x,
    'demand': y_noise
})

# include average interger.
df_interger_series = df_original_series[df_original_series['period'] % 1 == 0]
df_interger_series['period'] = df_interger_series['period'].div(np.pi).round(1)
plt.plot(df_interger_series['period'],df_interger_series['demand'],␣
 ↪marker='o',markersize=5)

# deseasonalize
series_deseasonalization = df_interger_series.loc[:, 'demand'].rolling(3).
 ↪mean().dropna()
series_deseasonalization=series_deseasonalization.
 ↪drop([series_deseasonalization.index[22],series_deseasonalization.index[23]])

# deseasonalize dataframe
df_deseasonalization = pd.DataFrame({
    'Quater': sum([[1,2,3]*8,[1,2]],[]),
    'Period': df_interger_series['period'] ,
    'Demand': df_interger_series['demand'] ,
    'Deseasonalized_Demand': series_deseasonalization
})
```

```
<ipython-input-4-ab869889bd6c>:8: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df_interger_series['period'] =
df_interger_series['period'].div(np.pi).round(1)
```



1.3 c. Calculate the seasonality factors

[5]:
```
#build up regressing model
reg = LinearRegression().fit(np.asarray(df_deseasonalization.loc[20:230,␣
↪'Period']).reshape(-1, 1),
                             df_deseasonalization.loc[:,␣
↪'Deseasonalized_Demand'].dropna())
#predict nan value
values = pd.Series(reg.predict(np.asarray(df_deseasonalization.loc[:,␣
↪'Period']).reshape(-1,1)))

#fill up nan value
df_deseasonalization.loc[0,['Deseasonalized_Demand']] = values[0]
df_deseasonalization.loc[10,['Deseasonalized_Demand']] = values[10]
df_deseasonalization.loc[240,['Deseasonalized_Demand']] = values[24]
df_deseasonalization.loc[250,['Deseasonalized_Demand']] = values[25]

# calculate seansonality factor
df_deseasonalization.loc[:, 'Seasonality'] = (df_deseasonalization.loc[:,␣
↪'Demand'] / df_deseasonalization.loc[:, 'Deseasonalized_Demand'])

df_Seasonality_bar= pd.DataFrame({
    'Quater': sum([[1,2,3]*8,[1,2]],[]),
    'Period': df_interger_series['period'] ,
    'Demand': df_interger_series['demand'] ,
```

```
    'Deseasonalized_Demand': series_deseasonalization
})

df_seasonality = df_deseasonalization.groupby(['Quater'], as_index=False).mean()
df_seasonality.loc[:, 'Seasonality_bar'] = df_seasonality.loc[:, 'Seasonality']
df_seasonality = df_seasonality[['Quater','Seasonality_bar']]
df_deseasonalization = pd.merge(df_deseasonalization,df_seasonality).
 ↪sort_values('Period')
```

[6]:

```
df_deseasonalization
```

[6]:

```
    Quater  Period     Demand  Deseasonalized_Demand  Seasonality  \
0        1     0.0  11.053918              10.119166     1.092374
9        2     0.3  10.455796               8.455223     1.236608
18       3     0.6   9.349128              10.286280     0.908893
1        1     1.0   8.266442               9.357122     0.883439
10       2     1.3   8.915853               8.843808     1.008146
19       3     1.6   9.245860               8.809385     1.049547
2        1     1.9  10.191551               9.451088     1.078347
11       2     2.2   9.306449               9.581287     0.971315
20       3     2.5   8.466014               9.321338     0.908240
3        1     2.9   7.573053               8.448505     0.896378
12       2     3.2   7.370566               7.803211     0.944555
21       3     3.5   8.116188               7.686602     1.055888
4        1     3.8   8.964254               8.150336     1.099863
13       2     4.1   8.599915               8.560119     1.004649
22       3     4.5   7.721453               8.428541     0.916108
5        1     4.8   6.722205               7.681191     0.875151
14       2     5.1   6.559955               7.001204     0.936975
23       3     5.4   7.043282               6.775147     1.039576
6        1     5.7   7.908110               7.170449     1.102875
15       2     6.0   7.541343               7.497578     1.005837
24       3     6.4   6.994145               7.481199     0.934896
7        1     6.7   6.166982               6.900824     0.893659
16       2     7.0   5.216677               6.125935     0.851572
25       3     7.3   5.902539               5.762066     1.024379
8        1     7.6   6.237170               6.167302     1.011329
17       2     8.0   6.930420               5.959309     1.162957

    Seasonality_bar
0          0.992602
9          1.013624
18         0.979691
1          0.992602
10         1.013624
19         0.979691
2          0.992602
```

```
11          1.013624
20          0.979691
3           0.992602
12          1.013624
21          0.979691
4           0.992602
13          1.013624
22          0.979691
5           0.992602
14          1.013624
23          0.979691
6           0.992602
15          1.013624
24          0.979691
7           0.992602
16          1.013624
25          0.979691
8           0.992602
17          1.013624
```

[7]:
```
df_seasonality
```

[7]:

	Quater	Seasonality_bar
0	1	0.992602
1	2	1.013624
2	3	0.979691

1.4 d. Finalize the model and evaluate the performance via MSE and MAPE

[8]:
```
# calulate Forecast, Error, Error_Squre, MSE, MAPE
df_deseasonalization.loc[:, 'Forecast'] =  (reg.predict(np.
 ↪asarray(df_deseasonalization.loc[:, 'Period']).reshape(-1,1)) *␣
 ↪df_deseasonalization.loc[:, 'Seasonality_bar'])
df_deseasonalization.loc[:, 'Error'] =  (df_deseasonalization.loc[:,␣
 ↪'Demand']-df_deseasonalization.loc[:, 'Forecast'])
df_deseasonalization.loc[:, 'Error_Squre'] =  (df_deseasonalization.loc[:,␣
 ↪'Error']*df_deseasonalization.loc[:, 'Error'])
MSE = df_deseasonalization['Error_Squre'].sum()/len(df_deseasonalization)
MAPE = ((abs(df_deseasonalization.loc[:, 'Error']) / abs(df_deseasonalization.
 ↪loc[:, 'Demand'])).sum())*100/len(df_deseasonalization)

print("Time-Series Model:")
print("MSE:",MSE.round(3))
print("MAPE:",MAPE.round(3))
```

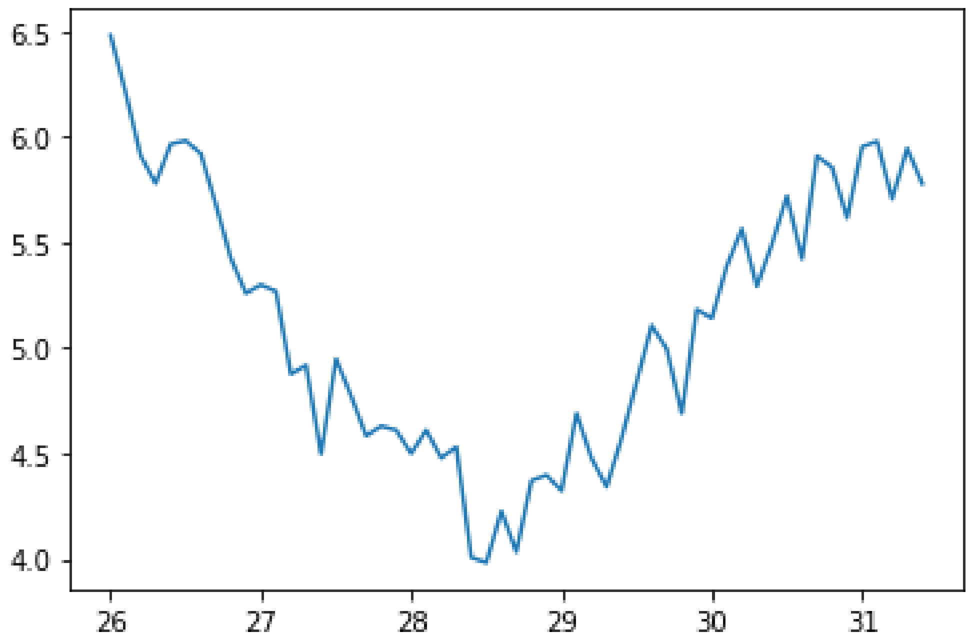
```
Time-Series Model:
MSE: 0.524
```

MAPE: 7.853

1.5 e. Use the static model to predict , = 25, … , 30. Use the “true” model to simulate 25, … , 30 and calculate the MSE and MAPE accordingly.

1.5.1 Construct further more data points(y=26~31)

[9]:
```
x = np.arange(26.0,10*np.pi,0.1)
y = 10+np.cos(x)-x/6

y_noise = []

for i in y:
    n = 0.3
    noise = np.random.uniform(-n,n)
    y_noise.append(i + noise)

plt.plot(x,y_noise)
plt.show()
```



1.5.2 Predicting while using true model

[10]:
```
#true model
df_true_model = pd.DataFrame({
    'Period': x,
    'Demand': y_noise,
```

```
    'Forecast':y,
})
df_true_model.loc[:, 'Error'] =  (df_true_model.loc[:, 'Demand']-df_true_model.
 ↪loc[:, 'Forecast'])
df_true_model.loc[:, 'Error_Squre'] =  (df_true_model.loc[:,␣
 ↪'Error']*df_true_model.loc[:, 'Error'])
MSE = df_true_model['Error_Squre'].sum()/len(df_true_model)
MAPE = ((abs(df_true_model.loc[:, 'Error']) / abs(df_true_model.loc[:,␣
 ↪'Demand'])).sum())*100/len(df_true_model)

print("True Model(y=26~31):")
print("MSE:",MSE.round(3))
print("MAPE:",MAPE.round(3))
```

```
True Model(y=26~31):
MSE: 0.031
MAPE: 3.02
```

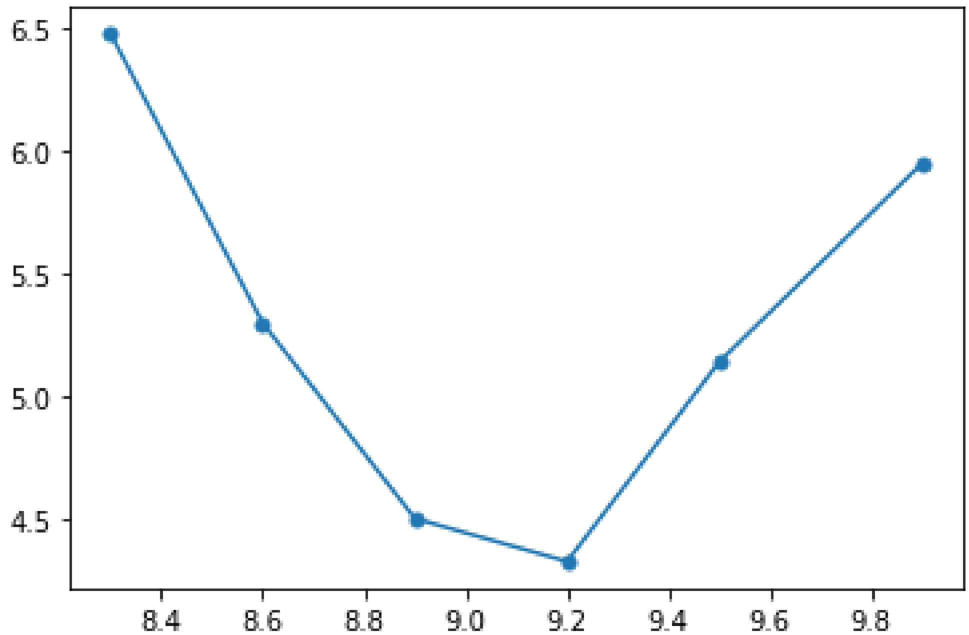
1.5.3 Predicting while using constructed model

[11]:
```
#time-series model
df_time_series_model = pd.DataFrame({
    'Period': x,
    'Demand': y_noise
})



df_interger_series = df_time_series_model[df_time_series_model['Period'].
 ↪round(1) % 1.0 == 0]
df_interger_series['Period'] = df_interger_series['Period'].div(np.pi).round(1)
plt.plot(df_interger_series['Period'],df_interger_series['Demand'],␣
 ↪marker='o',markersize=5)

df_time_series_deseasonalization= pd.DataFrame({   })
df_time_series_deseasonalization = pd.
 ↪merge(df_interger_series,df_deseasonalization, how="outer").
 ↪sort_values('Period')
df_time_series_deseasonalization.loc[:,'Quater']=sum([[1,2,3]*10,[1,2]],[])

df_time_series_deseasonalization=df_time_series_deseasonalization.
 ↪drop(['Seasonality_bar'], axis=1)
df_time_series_deseasonalization = pd.
 ↪merge(df_time_series_deseasonalization,df_seasonality,how = "outer").
 ↪sort_values('Period')
```

```
df_time_series_deseasonalization.loc[:, 'Forecast'] =  (reg.predict(np.
↪asarray(df_time_series_deseasonalization.loc[:, 'Period']).reshape(-1,1)) *␣
↪df_time_series_deseasonalization.loc[:, 'Seasonality_bar'])
df_time_series_deseasonalization.loc[:, 'Error'] = ␣
↪(df_time_series_deseasonalization.loc[:,␣
↪'Demand']-df_time_series_deseasonalization.loc[:, 'Forecast'])
df_time_series_deseasonalization.loc[:, 'Error_Squre'] = ␣
↪(df_time_series_deseasonalization.loc[:,␣
↪'Error']*df_time_series_deseasonalization.loc[:, 'Error'])
MSE = df_time_series_deseasonalization['Error_Squre'].sum()/
↪len(df_time_series_deseasonalization)
MAPE = ((abs(df_time_series_deseasonalization.loc[:, 'Error']) /␣
↪abs(df_time_series_deseasonalization.loc[:, 'Demand'])).sum())*100/
↪len(df_deseasonalization)

print("Time-Series Model(y=26~31):")
print("MSE:",MSE.round(3))
print("MAPE:",MAPE.round(3))
```

```
Time-Series Model(y=26~31):
MSE: 0.536
MAPE: 10.853
```

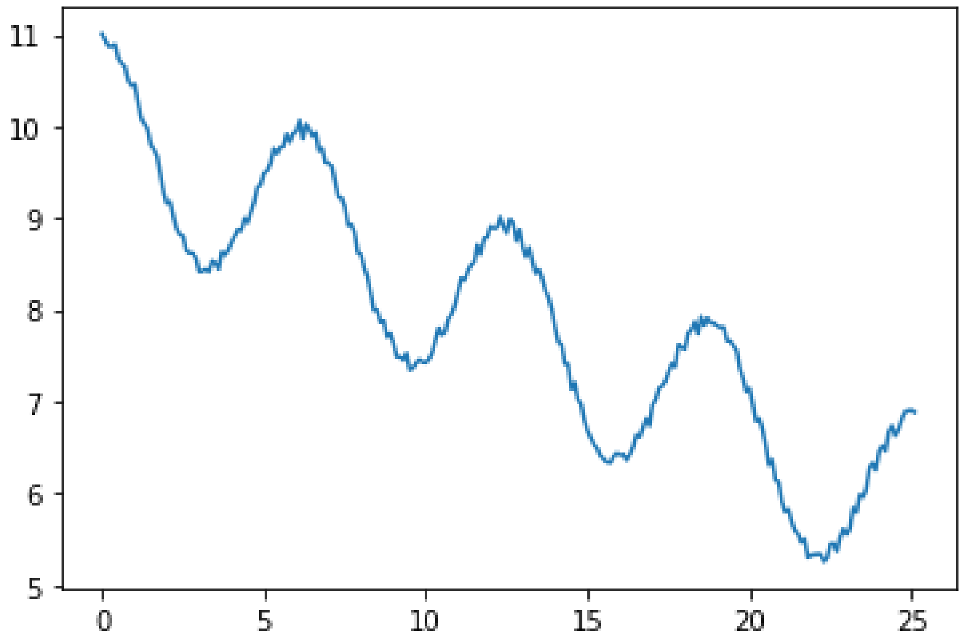
```
<ipython-input-11-c8e5766bbe8b>:9: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df_interger_series['Period'] =
df_interger_series['Period'].div(np.pi).round(1)
```



1.6 f. Modify the disturbance in (a) to change series (can be more or less fluctuating). Re-run the questions (b)-(d). What can you conclude when comparing to the results in (d) with the previous disturbance.

1.6.1 Change noise factor from 0.3 to 0.1.

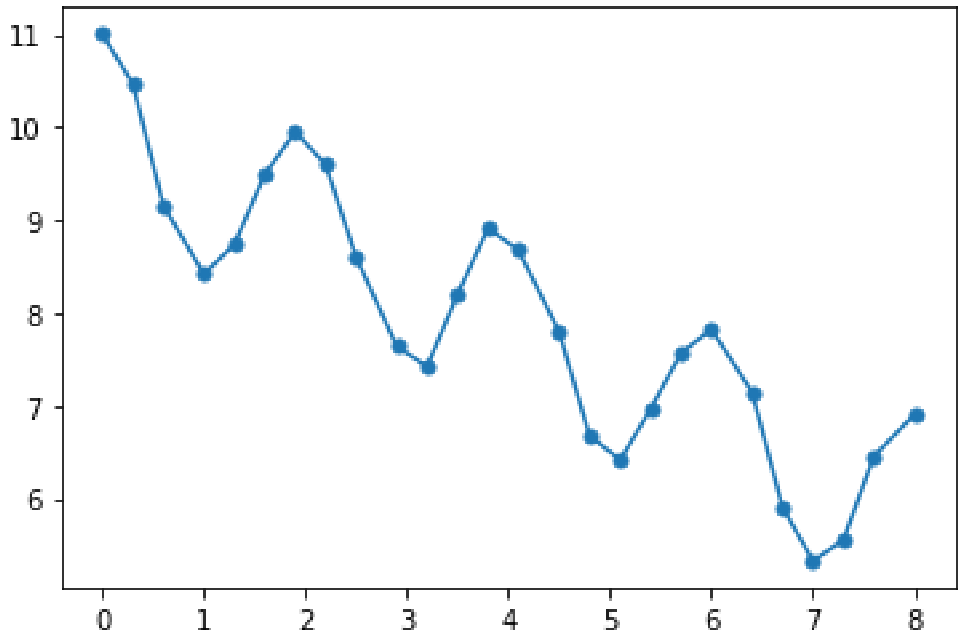
[12]:
```
x = np.arange(0,8*np.pi,0.1)
y = 10+np.cos(x)-x/6

y_noise = []

for i in y:
    n = 0.1
    noise = np.random.uniform(-n,n)
    y_noise.append(i + noise)

plt.plot(x,y_noise)
plt.show()
```



[13]:
```
df_original_series = pd.DataFrame({
    'period': x,
    'demand': y_noise
})

# include average interger.
df_interger_series = df_original_series[df_original_series['period'] % 1 == 0]
df_interger_series['period'] = df_interger_series['period'].div(np.pi).round(1)
plt.plot(df_interger_series['period'],df_interger_series['demand'],␣
 ↪marker='o',markersize=5)

# deseasonalize
series_deseasonalization = df_interger_series.loc[:, 'demand'].rolling(3).
 ↪mean().dropna()
series_deseasonalization=series_deseasonalization.
 ↪drop([series_deseasonalization.index[22],series_deseasonalization.index[23]])

# deseasonalize dataframe
df_deseasonalization = pd.DataFrame({
    'Quater': sum([[1,2,3]*8,[1,2]],[]),
    'Period': df_interger_series['period'] ,
    'Demand': df_interger_series['demand'] ,
    'Deseasonalized_Demand': series_deseasonalization
})
```

```
<ipython-input-13-ab869889bd6c>:8: SettingWithCopyWarning:
```

```
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df_interger_series['period'] =
df_interger_series['period'].div(np.pi).round(1)
```



[14]:
```python
#build up regressing model
reg = LinearRegression().fit(np.asarray(df_deseasonalization.loc[20:230,␣
↪'Period']).reshape(-1, 1),
                             df_deseasonalization.loc[:,␣
↪'Deseasonalized_Demand'].dropna())
#predict nan value
values = pd.Series(reg.predict(np.asarray(df_deseasonalization.loc[:,␣
↪'Period']).reshape(-1,1)))

df_deseasonalization.loc[0,['Deseasonalized_Demand']] = values[0]
df_deseasonalization.loc[10,['Deseasonalized_Demand']] = values[10]
df_deseasonalization.loc[240,['Deseasonalized_Demand']] = values[24]
df_deseasonalization.loc[250,['Deseasonalized_Demand']] = values[25]

# calculate seansonality factor
df_deseasonalization.loc[:, 'Seasonality'] = (df_deseasonalization.loc[:,␣
↪'Demand'] / df_deseasonalization.loc[:, 'Deseasonalized_Demand'])
```

```
df_Seasonality_bar= pd.DataFrame({
    'Quater': sum([[1,2,3]*8,[1,2]],[]),
    'Period': df_interger_series['period'] ,
    'Demand': df_interger_series['demand'] ,
    'Deseasonalized_Demand': series_deseasonalization
})

df_seasonality = df_deseasonalization.groupby(['Quater'], as_index=False).mean()
df_seasonality.loc[:, 'Seasonality_bar'] = df_seasonality.loc[:, 'Seasonality']
df_seasonality = df_seasonality[['Quater','Seasonality_bar']]

df_deseasonalization = pd.merge(df_deseasonalization,df_seasonality).
 ↪sort_values('Period')
```

[15]:
```
df_deseasonalization.loc[:, 'Forecast'] =  (reg.predict(np.
 ↪asarray(df_deseasonalization.loc[:, 'Period']).reshape(-1,1)) *␣
 ↪df_deseasonalization.loc[:, 'Seasonality_bar'])
df_deseasonalization.loc[:, 'Error'] =  (df_deseasonalization.loc[:,␣
 ↪'Demand']-df_deseasonalization.loc[:, 'Forecast'])
df_deseasonalization.loc[:, 'Error_Squre'] =  (df_deseasonalization.loc[:,␣
 ↪'Error']*df_deseasonalization.loc[:, 'Error'])
MSE = df_deseasonalization['Error_Squre'].sum()/len(df_deseasonalization)
MAPE = ((abs(df_deseasonalization.loc[:, 'Error']) / abs(df_deseasonalization.
 ↪loc[:, 'Demand'])).sum())*100/len(df_deseasonalization)

print("Time-Series Model(less disturbance):")
print("MSE:",MSE.round(3))
print("MAPE:",MAPE.round(3))
```

```
Time-Series Model(less disturbance):
MSE: 0.546
MAPE: 8.679
```

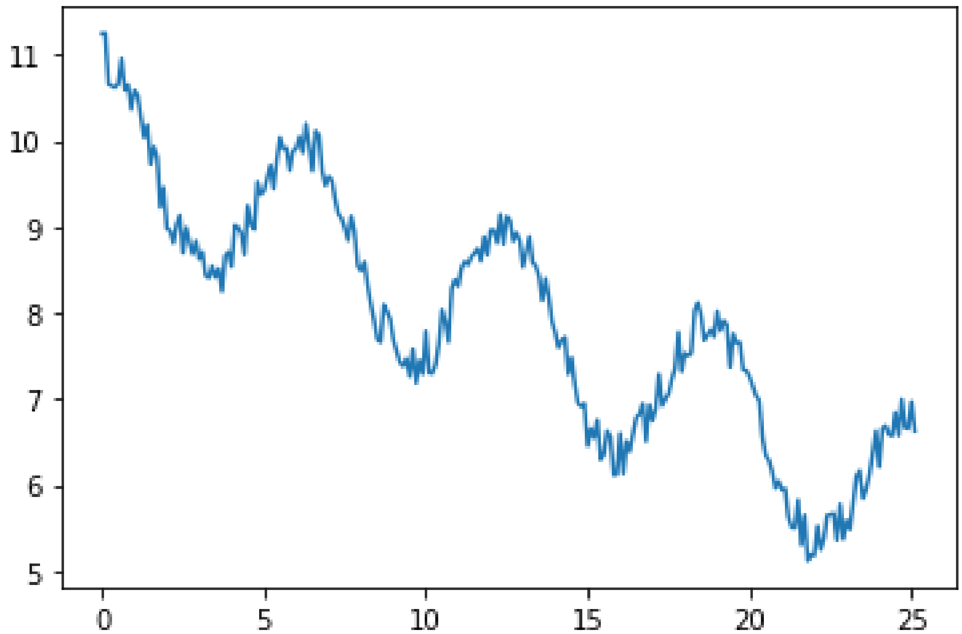
1.6.2 In this disturbance data simulation, we have better performance in both MSE and MAPE than previous model

2 Q2

2.0.1 rearrange the data

[16]:
```
x = np.arange(0,8*np.pi,0.1)
y = 10+np.cos(x)-x/6

y_noise = []

for i in y:
    n = 0.3
```

```
    noise = np.random.uniform(-n,n)
    y_noise.append(i + noise)

plt.plot(x,y_noise)
plt.show()
```

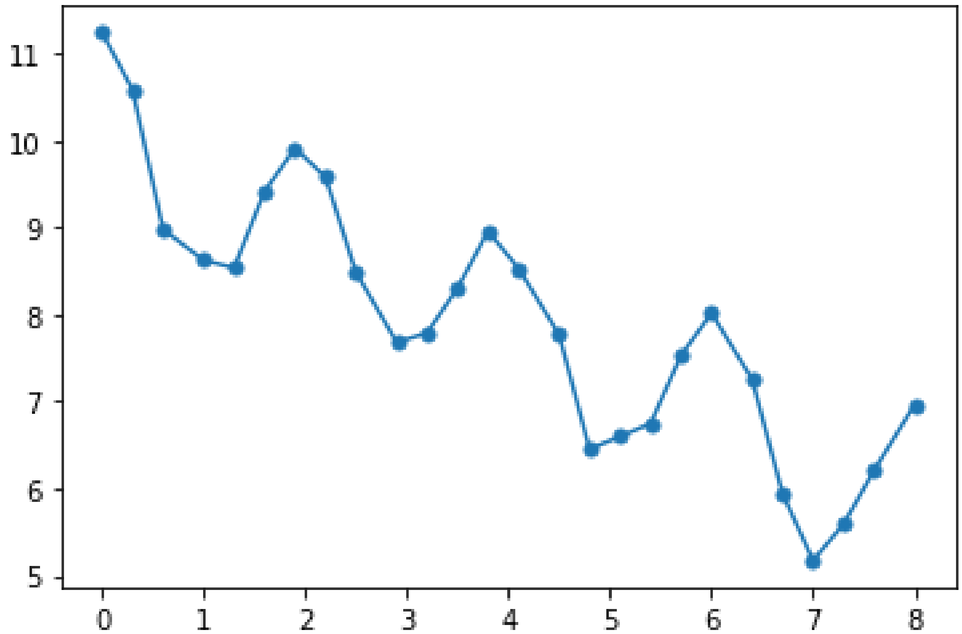


[17]:

```
df_original_series = pd.DataFrame({
    'Period': x,
    'Demand': y_noise
})

# include average interger.
df_interger_series = df_original_series[df_original_series['Period'] % 1 == 0]
df_interger_series['Period'] = df_interger_series['Period'].div(np.pi).round(1)
plt.plot(df_interger_series['Period'],df_interger_series['Demand'],␣
 ↪marker='o',markersize=5)
```

```
<ipython-input-17-e09ded7e73c9>:8: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df_interger_series['Period'] =
df_interger_series['Period'].div(np.pi).round(1)
```

[17]: [<matplotlib.lines.Line2D at 0x16ba3c51f10>]



[18]:
```
# train the data with Holt-Winters algorithms with statsmodels module.
HWES_model = HWES(df_interger_series.loc[:, 'Demand'], seasonal_periods=3,␣
 ↪trend='add', seasonal='mul')
HWES_fit_report = HWES_model.fit()
print(HWES_fit_report.summary())
```

```
                       ExponentialSmoothing Model Results
================================================================================
Dep. Variable:                       Demand   No. Observations:                 26
Model:                 ExponentialSmoothing   SSE                           13.224
Optimized:                             True   AIC                           -3.578
Trend:                             Additive   BIC                            5.229
Seasonal:                    Multiplicative   AICC                           7.672
Seasonal Periods:                         3   Date:                 Sun, 10 Oct 2021
Box-Cox:                              False   Time:                         22:34:05
Box-Cox Coeff.:                        None
================================================================================
=
                          coeff                 code              optimized
--------------------------------------------------------------------------------
-
smoothing_level               1.0000000                alpha
True
smoothing_trend              4.8631e-13                 beta
```

```
True
smoothing_seasonal          1.5746e-09                gamma
True
initial_level                7.1094084                  l.0
True
initial_trend               -0.1086316                  b.0
True
initial_seasons.0            1.6064587                  s.0
True
initial_seasons.1            1.6246751                  s.1
True
initial_seasons.2            1.5939570                  s.2
True
--------------------------------------------------------------------------------
-

C:\Users\TerryYang\anaconda3\envs\TENSORFLOW\lib\site-
packages\statsmodels\tsa\base\tsa_model.py:578: ValueWarning: An unsupported
index was provided and will be ignored when e.g. forecasting.
  warnings.warn('An unsupported index was provided and will be'
C:\Users\TerryYang\anaconda3\envs\TENSORFLOW\lib\site-
packages\statsmodels\tsa\holtwinters\model.py:427: FutureWarning: After 0.13
initialization must be handled at model creation
  warnings.warn(
```