# Graph Construction Using Python

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# 19/11/2019 ~ LAB 1

## NetworkX Package

NetworkX is a Python Package for the creation, manipulation and study of the structure, dynamics and functions of complex networks.
NetworkX provides:
i) Tools for the study of the structure and dynamics of social, biological and infrastructure networks;
ii) A standard programming interface and graph implementation that is suitable for many applications;
iii) A rapid development environment for collaborative, multidisciplinary projects;
iv) An interface to existing numerical algorithms and code written in C, C++ and FORTRAN.
v) The ability to painlessly work with large nonstandard data sets.
With NetworkX you can load and store networks in standard and nonstandard data formats, generate many types of random and classic networks, analyze netwrok structure, build network models, design new network algorithms, draw networks and much more.

## Matplotlib

Even though Networkx provides basic functionality for visualizing graphs, it is primarily intended mainly for enabling graph analysis rather than performing graph visualization. For graph visualization, we will have to use specific tools, like Matplotlib, dedicated for this purpose

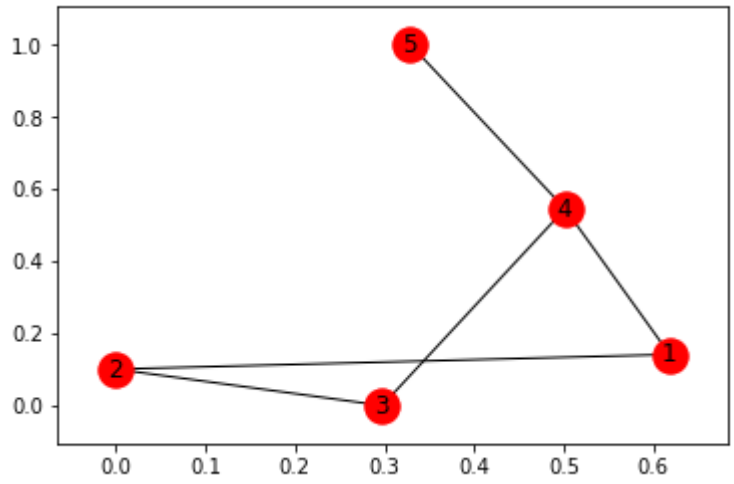
In [1]:

```
import networkx as nx
import matplotlib.pyplot as plt
```

The graph G can be in several ways. NetworkX includes many graph generator functions and facilties to read and write graphs in many formats. To get started though we'll look at simple manipulations.
You can add 1 node at a time as shown below,

In [39]:

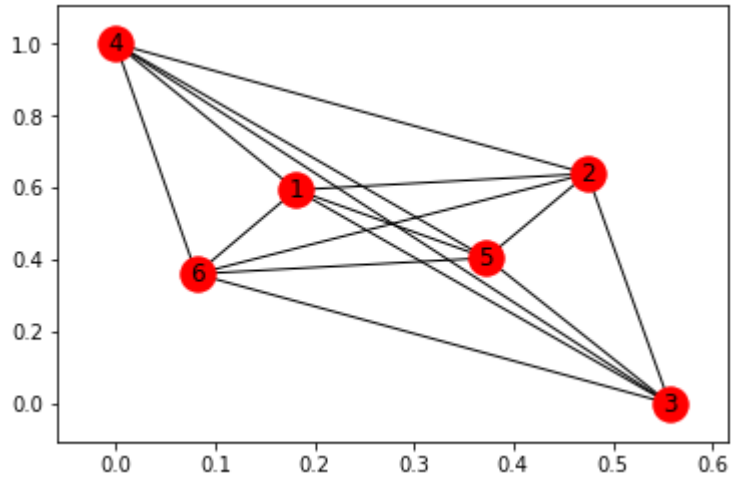
```
G = nx.Graph()
G.add_node('1')
G.add_node('2')
G.add_node('3')
G.add_node('4')
G.add_node('5')
G.add_edge('1','2')
G.add_edge('2','3')
G.add_edge('3','4')
G.add_edge('4','1')
G.add_edge('4','5')
nx.draw_networkx(G)
```




## Construct the complete graph on 6 vertices

In [38]:

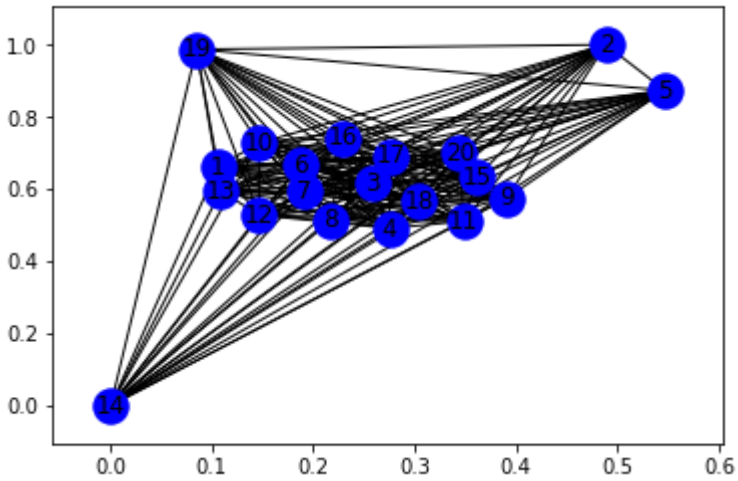
```
G = nx.Graph()
G.add_node('1')
G.add_node('2')
G.add_node('3')
G.add_node('4')
G.add_node('5')
G.add_node('6')
G.add_edge('1','2')
G.add_edge('1','3')
G.add_edge('1','4')
G.add_edge('1','5')
G.add_edge('1','6')
G.add_edge('2','3')
G.add_edge('2','4')
G.add_edge('2','5')
G.add_edge('2','6')
G.add_edge('3','2')
G.add_edge('3','4')
G.add_edge('3','5')
G.add_edge('3','6')
G.add_edge('4','5')
G.add_edge('4','6')
G.add_edge('5','6')
nx.draw_networkx(G)
plt.show()
```



In [36]:

```
import networkx as nx
import matplotlib.pyplot as plt

def comp(n,cr):
    K = nx.Graph()
    for i in range(1,n+1):
        K.add_node(i)
        for j in range(i+1,n+1):
            K.add_edge(i,j)
    nx.draw_networkx(K,node_color=cr)
    plt.show()

num = input("Enter the number of vertices for a complete graph: ")
cl = input("Enter the color: ")
comp(int(num),cl)
```

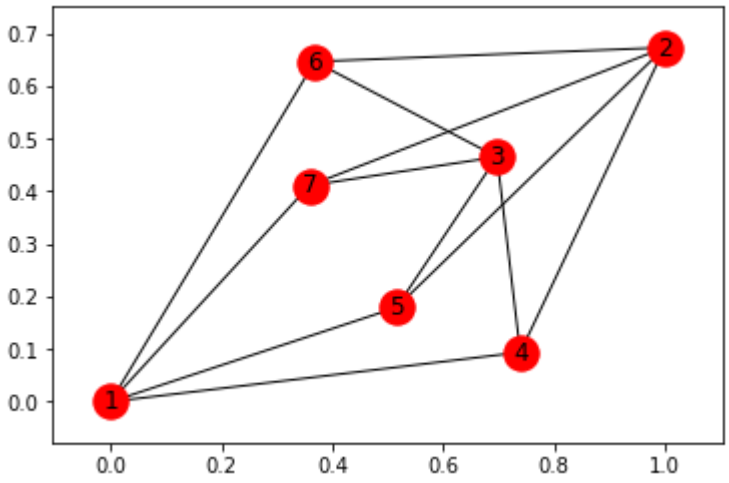
```
Enter the number of vertices for a complete graph: 20
Enter the color: blue
```




## Draw a complete bi - partite graph $K_{3,4}$

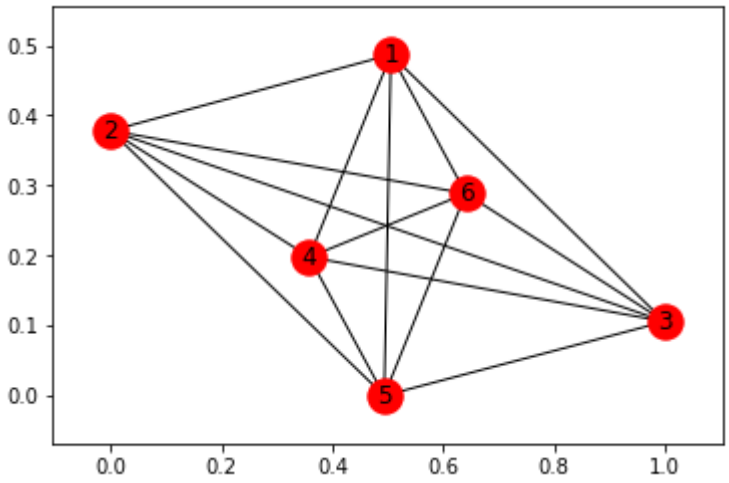
In [34]:

```
G = nx.Graph()
G.add_node('1')
G.add_node('2')
G.add_node('3')
G.add_node('4')
G.add_node('5')
G.add_node('6')
G.add_node('7')
G.add_edge('1','4')
G.add_edge('1','5')
G.add_edge('1','6')
G.add_edge('1','7')
G.add_edge('2','4')
G.add_edge('2','5')
G.add_edge('2','6')
G.add_edge('2','7')
G.add_edge('3','4')
G.add_edge('3','5')
G.add_edge('3','6')
G.add_edge('3','7')
nx.draw_networkx(G)
plt.show()
```



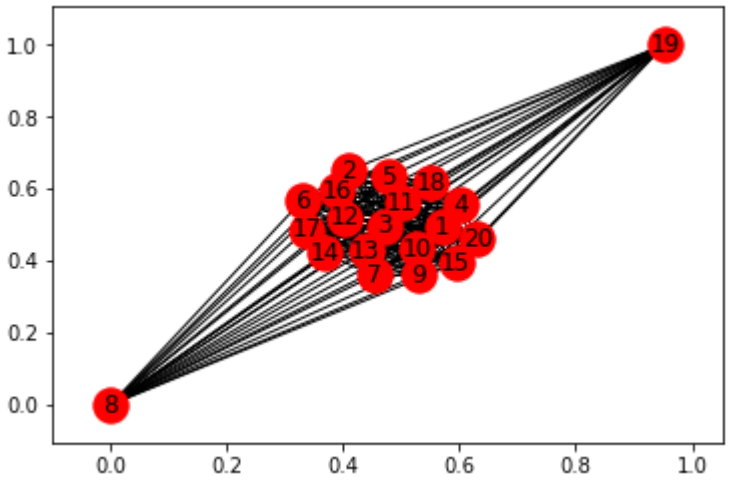
In [33]:

```
G = nx.Graph()
G.add_nodes_from([1,2,3,4,5,6]) #adding a list of nodes by passing a list argument
G.add_edges_from([(1,2),(1,3),(1,4),(1,5),(1,6),
                  (2,3),(2,4),(2,5),(2,6),
                  (3,4),(3,5),(3,6),
                  (4,5),(4,6),
                  (5,6)]) # adding edges from a alist
nx.draw_networkx(G,with_labels = True)
plt.show()
```




In [40]:

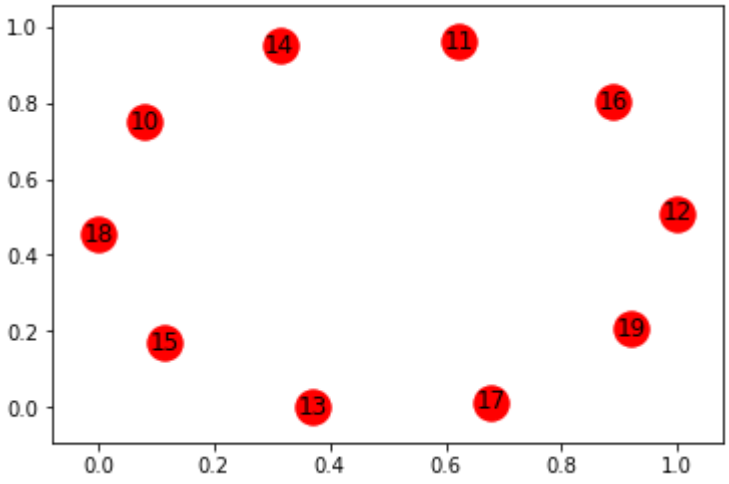
```
comp(20,"Red")
```




## Other ways to add nodes using range function

In [42]:

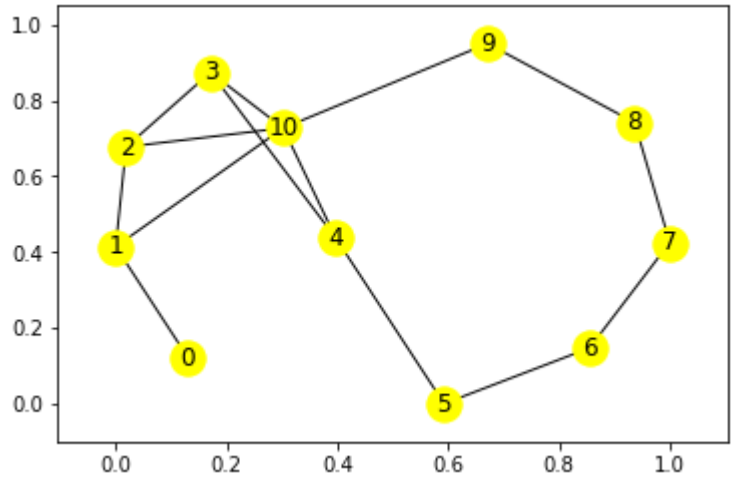
```
G = nx.Graph()
G.add_nodes_from(range(10,20))
nx.draw_networkx(G)
plt.show()
```




# 26/11/2019

In [29]:

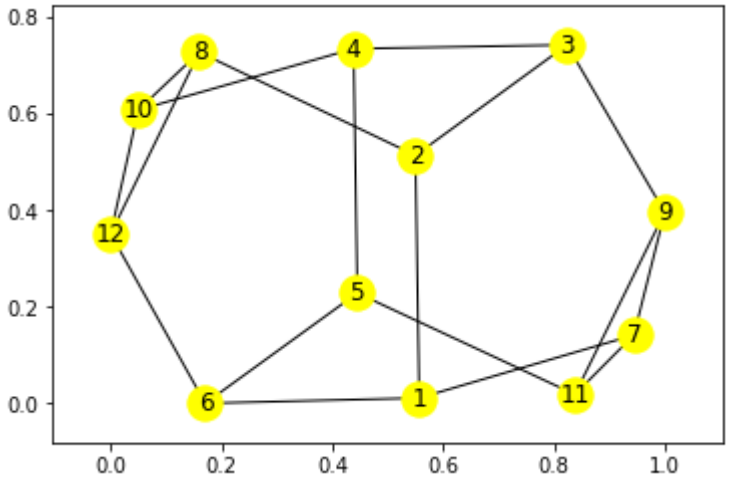
```
G = nx.Graph()
G.add_nodes_from(range(0,10))
e0 = (0,1)
e1 = (1,2)
e2 = (2,3)
e3 = (3,4)
e4 = (4,5)
e5 = (5,6)
e6 = (6,7)
e7 = (7,8)
e8 = (8,9)
e9 = (9,10)
e10 = (10,0)
e11 = (10,1)
e12 = (10,2)
e13 = (10,3)
e14 = (10,4)
G.add_edge(*e0)
G.add_edge(*e1)
G.add_edge(*e2)
G.add_edge(*e3)
G.add_edge(*e4)
G.add_edge(*e5)
G.add_edge(*e6)
G.add_edge(*e7)
G.add_edge(*e8)
G.add_edge(*e9)
G.add_edge(*e1)
G.add_edge(*e11)
G.add_edge(*e12)
G.add_edge(*e13)
G.add_edge(*e14)
nx.draw_networkx(G,node_color="yellow")
plt.show()
```




# Construct the Herschel's Graph P(6,2)
# 2 = Skips 1 vertex + 1

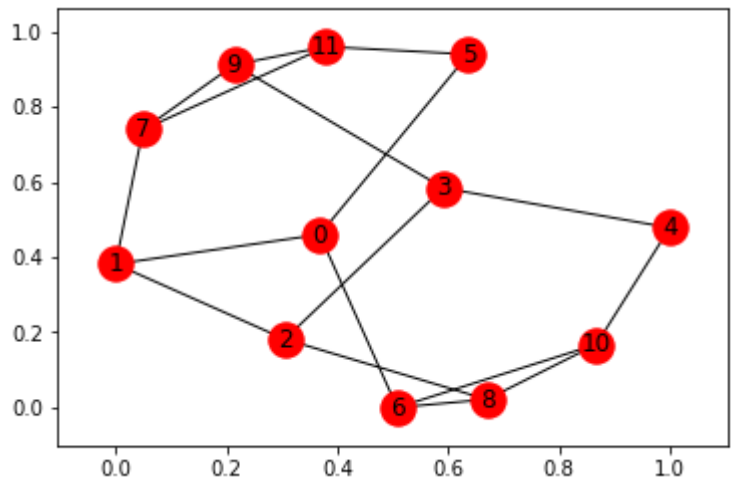
In [71]:

```
#Construct a Herschel graph which is denotd by P(6,2).
G=nx.Graph()
G.add_nodes_from(range(1,13))
G.add_edges_from([(1,2),(2,3),(3,4),(4,5),(5,6),(1,6),(1,7),(2,8),(3,9),(4,10),(5,11),(6,12
                  (9,11),(10,12)])
nx.draw_networkx(G,labels=dict([(1,"1"),(2,"2"),(3,"3"),(4,"4"),(5,"5"),(6,"6"),(7,"7"),(8,
        node_color="Yellow")
plt.show()
```



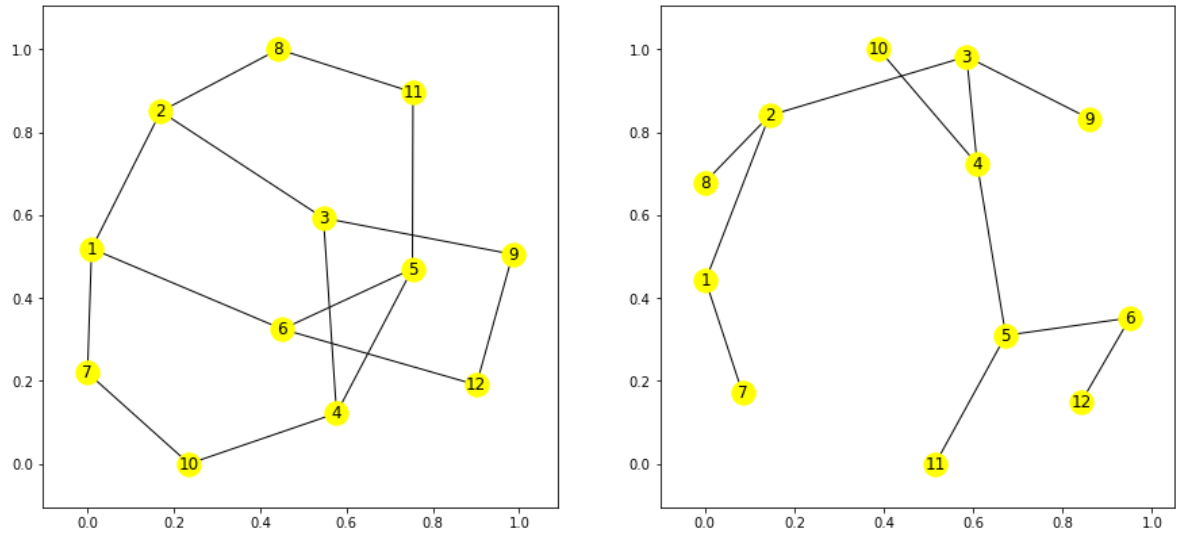
In [47]:

```
G = nx.Graph()
G.add_nodes_from(range(0,12))
e0 = (0,1)
e1 = (0,6)
e2 = (0,5)
e3 = (1,2)
e4 = (1,7)
e5 = (2,3)
e6 = (2,8)
e7 = (3,9)
e8 = (3,4)
e9 = (4,10)
e10 = (4,5)
e11 = (5,11)
e12 = (6,8)
e13 = (8,10)
e14 = (10,6)
e15 = (11,7)
e16 = (7,9)
e17 = (9,11)
G.add_edge(*e0)
G.add_edge(*e1)
G.add_edge(*e2)
G.add_edge(*e3)
G.add_edge(*e4)
G.add_edge(*e5)
G.add_edge(*e6)
G.add_edge(*e7)
G.add_edge(*e8)
G.add_edge(*e9)
G.add_edge(*e1)
G.add_edge(*e11)
G.add_edge(*e12)
G.add_edge(*e13)
G.add_edge(*e14)
G.add_edge(*e15)
G.add_edge(*e16)
G.add_edge(*e17)
nx.draw_networkx(G)
plt.show()
```



In [3]:

```
#Construct P(6,3) (the generalized Petersen graph). Obtain a minimal connected spanning sub
plt.figure(figsize=(15,15))
plt.subplot(2,2,1)
G=nx.Graph()
#G.add_title("G")
G.add_nodes_from(range(1,13))
G.add_edges_from([(1,2),(2,3),(3,4),(4,5),(5,6),(1,6),(1,7),(2,8),(3,9),(4,10),(5,11),(6,12
nx.draw_networkx(G,labels=dict([(1,"1"),(2,"2"),(3,"3"),(4,"4"),(5,"5"),(6,"6"),(7,"7"),(8,
        node_color="Yellow")
plt.subplot(2,2,2)
H=nx.Graph()
H.add_nodes_from(G)
H.add_edges_from([(1,2),(2,3),(3,4),(4,5),(5,6),(1,7),(2,8),(3,9),(4,10),(5,11),(6,12)])
nx.draw_networkx(H,labels=dict([(1,"1"),(2,"2"),(3,"3"),(4,"4"),(5,"5"),(6,"6"),(7,"7"),(8,
        node_color="Yellow")
plt.show()
```



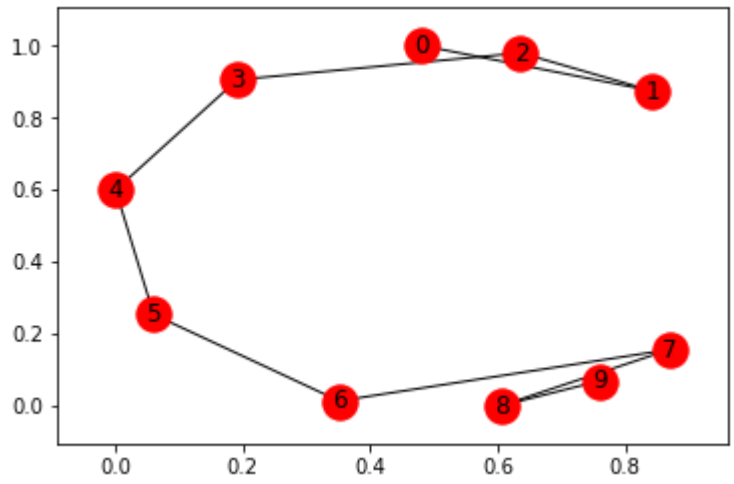

# Create a spanning subgraph

### Construct the P(6,3) graph. Obtain a minimal connected spanning subgraph of this graph.
### 3 = number of vertices it skips + 1

# 03/12/2019

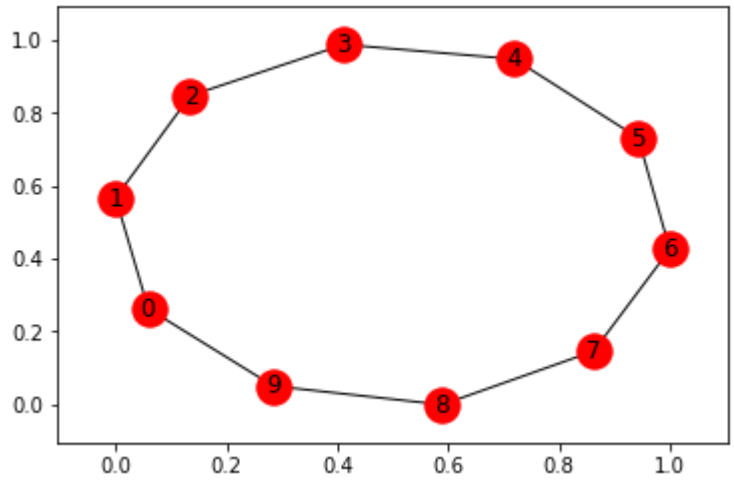
In [7]:

```
G = nx.path_graph(10)
nx.draw_networkx(G)
plt.show()
```



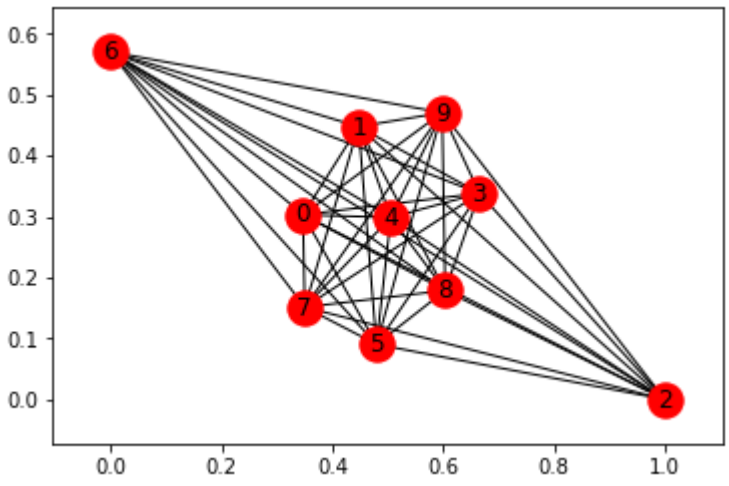

In [14]:

```
G = nx.cycle_graph(10)
nx.draw_networkx(G)
plt.show()
```



In [15]:

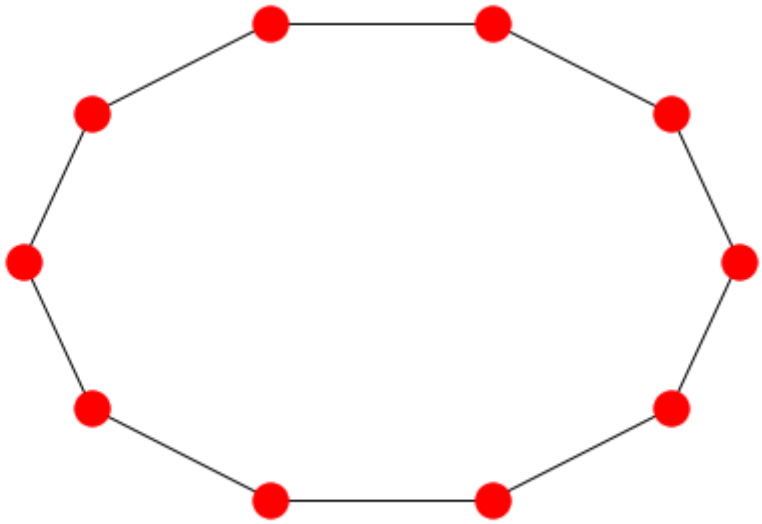
```
G = nx.complete_graph(10)
nx.draw_networkx(G)
plt.show()
```



In [16]:

```
G = nx.cycle_graph(10)
nx.draw_circular(G)
plt.show()
```

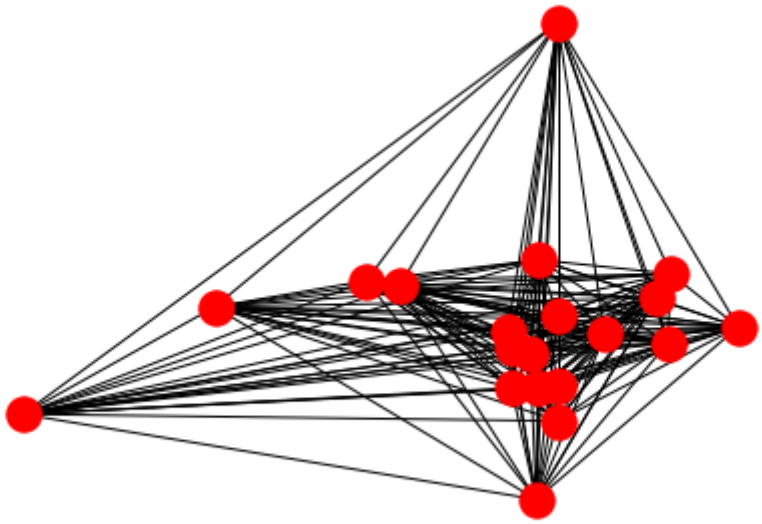
```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
Warning: axes.hold is deprecated. Please remove it from your matplotlibrc an
d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```



In [23]:

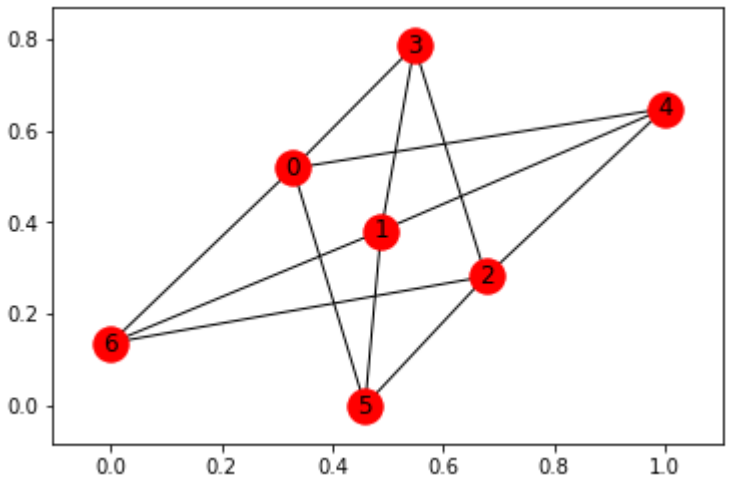
```
G = nx.complete_graph(20)
nx.draw_spectral(G)
plt.show()
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
Warning: axes.hold is deprecated. Please remove it from your matplotlibrc an
d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```



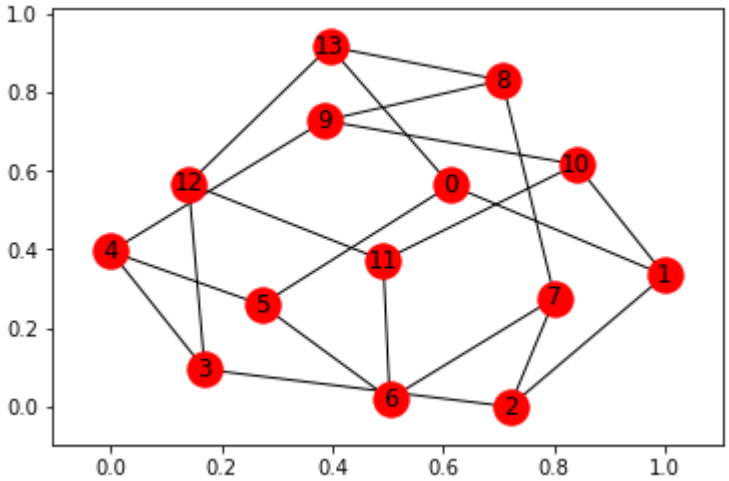
In [20]:

```
G = nx.complete_bipartite_graph(3,4)
nx.draw_networkx(G)
plt.show()
```




In [25]:

```
G = nx.heawood_graph()
nx.draw_networkx(G)
plt.show()
```



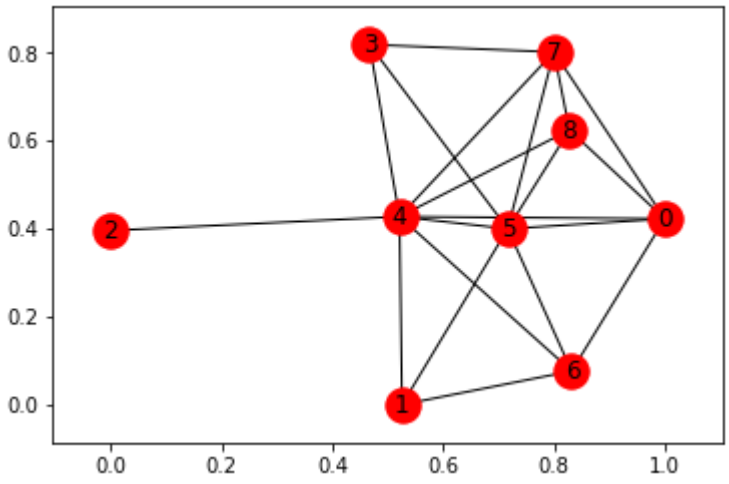

In [26]:

```
print(nx.info(G))
```

```
Name: Heawood Graph
Type: Graph
Number of nodes: 14
Number of edges: 21
Average degree:   3.0000
```

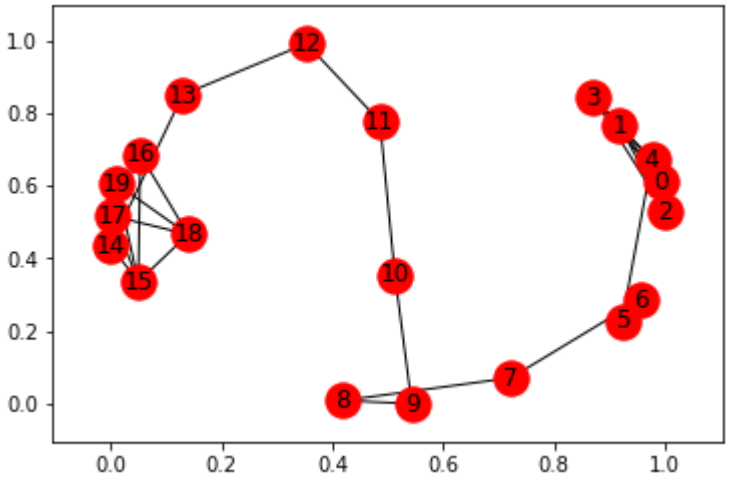
In [5]:

```
g = nx.barabasi_albert_graph(9,4)
nx.draw_networkx(g)
plt.show()
```




In [6]:

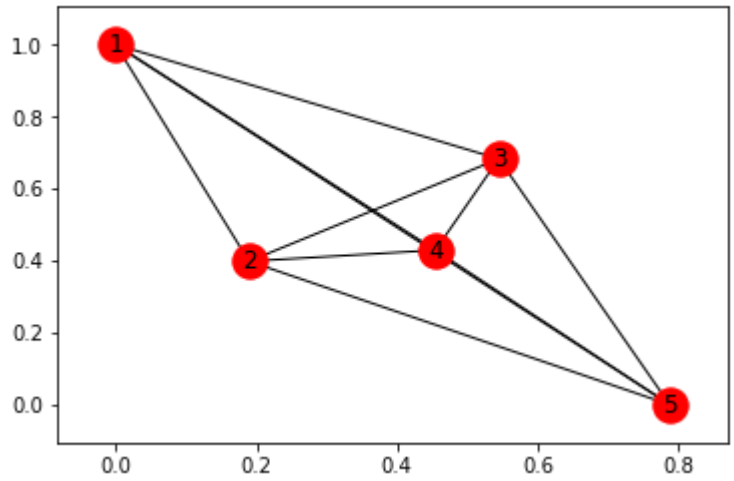
```
g = nx.barbell_graph(5,10)
nx.draw_networkx(g)
plt.show()
```




# Construct a complete graph on 5 vertices. Find it's 1 vertex deleted subgraph and 1 edge deleted subgraph.

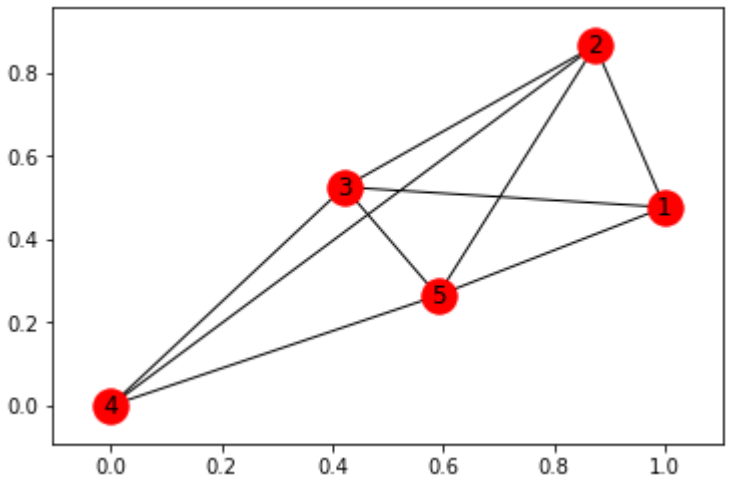
In [24]:

```
G = nx.Graph()
G.add_node('1')
G.add_node('2')
G.add_node('3')
G.add_node('4')
G.add_node('5')

G.add_edge('1','2')
G.add_edge('1','3')
G.add_edge('1','4')
G.add_edge('1','5')
G.add_edge('2','3')
G.add_edge('2','4')
G.add_edge('2','5')
G.add_edge('3','1')
G.add_edge('3','4')
G.add_edge('3','5')
G.add_edge('4','5')

nx.draw_networkx(G,with_labels = True)
plt.show()
```



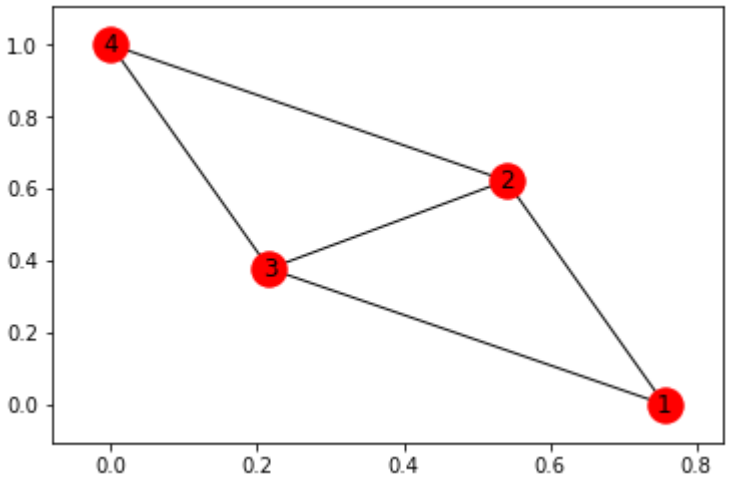
In [25]:

```
G.remove_edge('1','4')
nx.draw_networkx(G)
plt.show()
```




In [26]:

```
G.remove_node('5')
nx.draw_networkx(G)
plt.show()
```



In [8]:

```
DG = nx.dodecahedral_graph()
shells = [[2,3,4,5,6],[8,1,0,19,18,17,16,15,14,7],[9,10,11,12,13]]
nx.draw_shell(DG,nlist=shells,with_labels=True)
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
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  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
Warning: axes.hold is deprecated. Please remove it from your matplotlibrc an
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  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

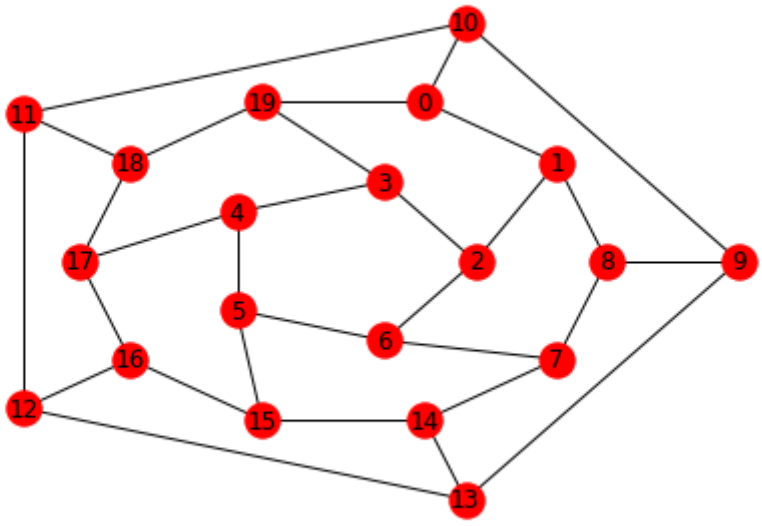

In [11]:

```
PG = nx.dodecahedral_graph()
shells = [[0,1,2,3,4],[5,6,7,8,9],[10,11,12,13,14],[15,16,17,18,19]]
nx.draw_shell(PG,nlist=shells,with_labels=True)
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
Warning: axes.hold is deprecated. Please remove it from your matplotlibrc an
d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

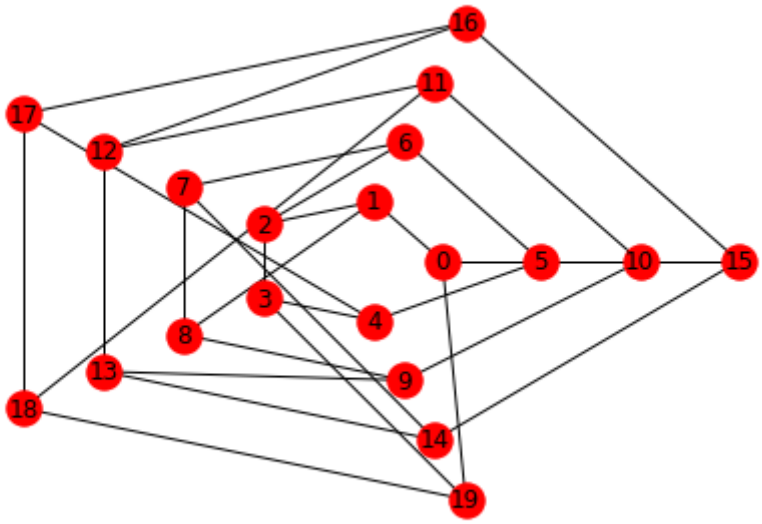


# Find number of vertices, edges, average between the node list, the edge list and the degree sequence of the ladder graph $L_{10}$

In [24]:

```
LG = nx.ladder_graph(10)
nx.draw(LG, with_labels=True, node_color="yellow")
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

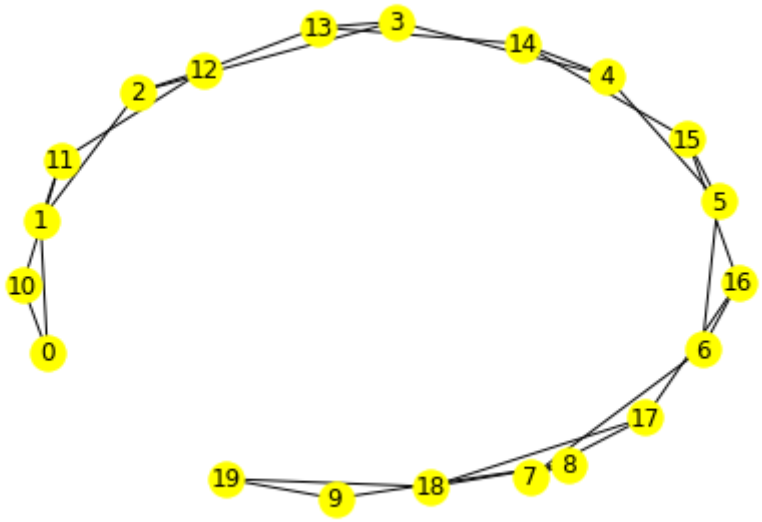


In [21]:

```
print(nx.info(LG))
print(LG.degree())
```

```
Name: ladder_graph_(10)
Type: Graph
Number of nodes: 20
Number of edges: 28
Average degree:   2.8000
{0: 2, 1: 3, 2: 3, 3: 3, 4: 3, 5: 3, 6: 3, 7: 3, 8: 3, 9: 2, 10: 2, 11: 3, 1
2: 3, 13: 3, 14: 3, 15: 3, 16: 3, 17: 3, 18: 3, 19: 2}
```

In [32]:

```
G = nx.Graph()
G.add_edges_from([(1,2),(1,3)])
G.add_node("spam")
nx.draw(G,with_labels=True)
plt.show()
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
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  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
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  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

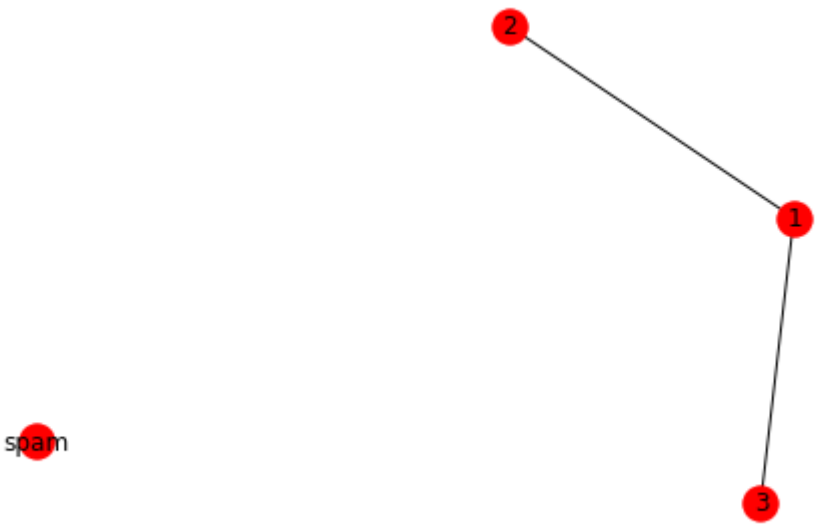


In [33]:

```
list(nx.connected_components(G))
```

Out[33]:

```
[{1, 2, 3}, {'spam'}]
```

In [34]:

```
sorted(d for n, d in G.degree())
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-34-8edead1260f2> in <module>()
----> 1 sorted(d for n, d in G.degree())

<ipython-input-34-8edead1260f2> in <genexpr>(.0)
----> 1 sorted(d for n, d in G.degree())

TypeError: 'int' object is not iterable
```

In [29]:

```
G = nx.Graph()
G.add_node('1')
G.add_node('2')
G.add_node('3')
G.add_node('4')
G.add_node('5')
G.add_node('6')
G.add_node('7')
G.add_edges_from([(1,4),(1,6),(2,5),(2,7),(3,5),(3,7)])
nx.draw(G,with_labels=True)
plt.show()
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```
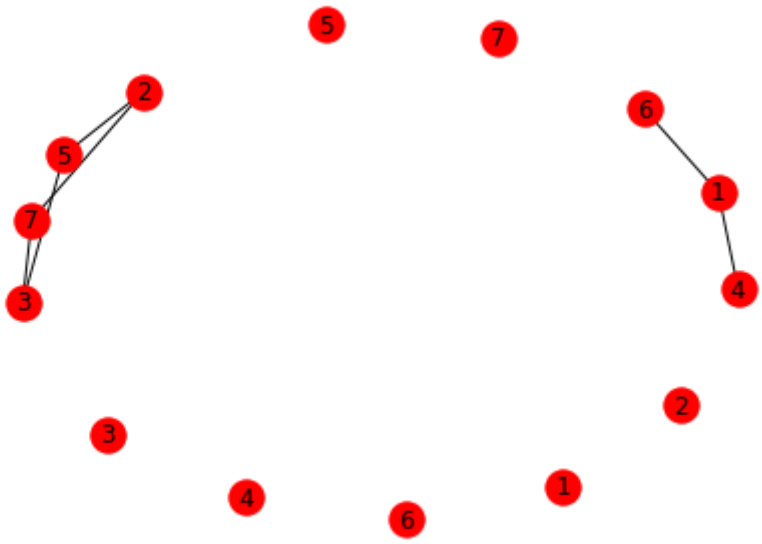




# 21/01/2020

In [2]:

```
import networkx as nx
import matplotlib.pyplot as plt
```

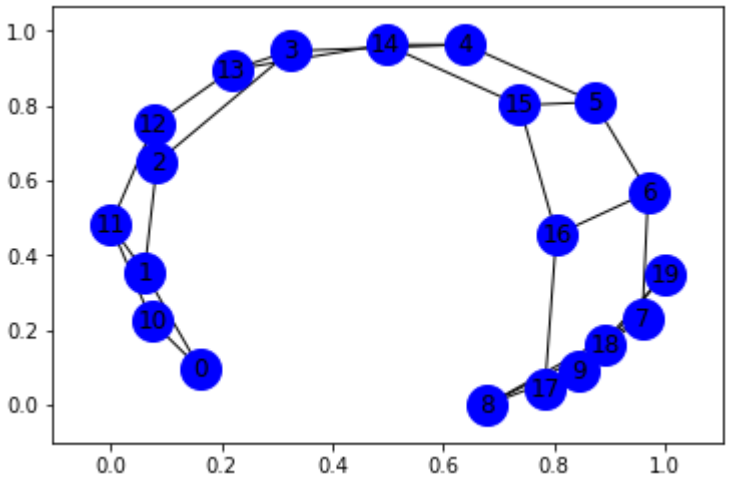
The adjacency list of all vertices of a given graph can be prepared using the command "nx.to_dict_of_lists(g)". See the following example:

In [29]:

```
g = nx.ladder_graph(10)
nx.draw_networkx(g,node_color='blue',node_size=400)
nx.to_dict_of_lists(g)
```

Out[29]:

```
{0: [1, 10],
 1: [0, 2, 11],
 2: [1, 3, 12],
 3: [2, 4, 13],
 4: [3, 5, 14],
 5: [4, 6, 15],
 6: [5, 7, 16],
 7: [6, 8, 17],
 8: [7, 9, 18],
 9: [8, 19],
 10: [11, 0],
 11: [10, 12, 1],
 12: [11, 13, 2],
 13: [12, 14, 3],
 14: [13, 15, 4],
 15: [14, 16, 5],
 16: [15, 17, 6],
 17: [16, 18, 7],
 18: [17, 19, 8],
 19: [18, 9]}
```

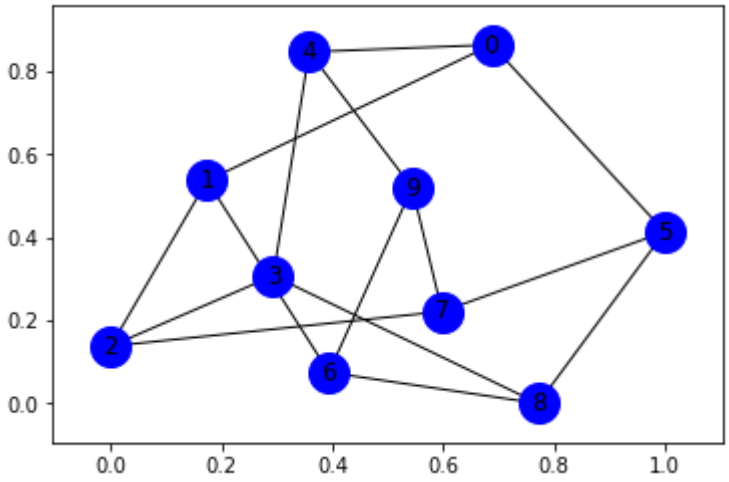


In [45]:

```
g = nx.petersen_graph()
nx.draw_networkx(g,node_color='blue',node_size=400)
nx.to_dict_of_lists(g)
```

Out[45]:

```
{0: [1, 4, 5],
 1: [0, 2, 6],
 2: [1, 3, 7],
 3: [2, 4, 8],
 4: [0, 3, 9],
 5: [0, 7, 8],
 6: [1, 8, 9],
 7: [2, 5, 9],
 8: [3, 5, 6],
 9: [4, 6, 7]}
```




# Draw the graph corresponding to the following adjacency list:

### 0: [1,4,6],

### 1: [0,2,11],

### 2: [1,3,12],

### 3: [2,4,13],

### 4: [3,5,14],

### 5: [4,6,15],

### 6: [5,7,16],

### 7: [6,8,17]

In [ ]:

```
g = nx.Graph()
g.add_nodes_from([])
```

In [46]:

```
g = nx.cycle_graph(10)
nx.draw(g)
nx.to_edgelist(g)
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
Warning: axes.hold is deprecated. Please remove it from your matplotlibrc an
d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```
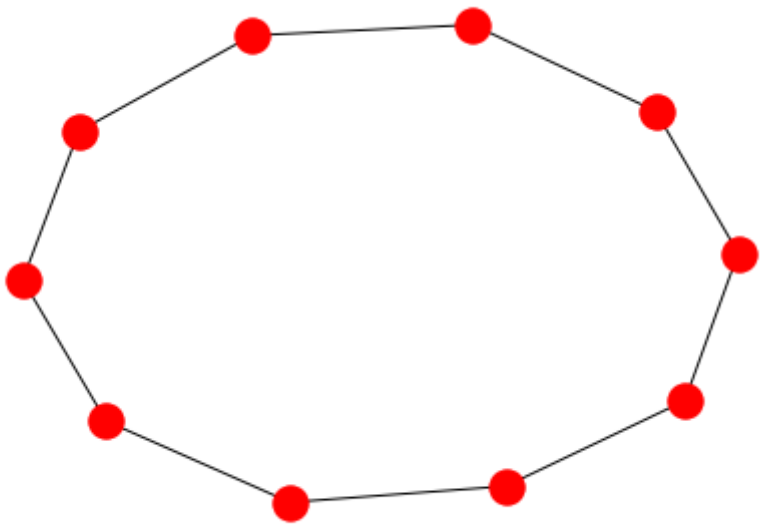

Out[46]:

```
[(0, 1, {}),
 (0, 9, {}),
 (1, 2, {}),
 (2, 3, {}),
 (3, 4, {}),
 (4, 5, {}),
 (5, 6, {}),
 (6, 7, {}),
 (7, 8, {}),
 (8, 9, {})]
```



In [47]:

```
G = nx.cycle_graph(10)
nx.draw(G)
plt.show()
X = nx.adj_matrix(G)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
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C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

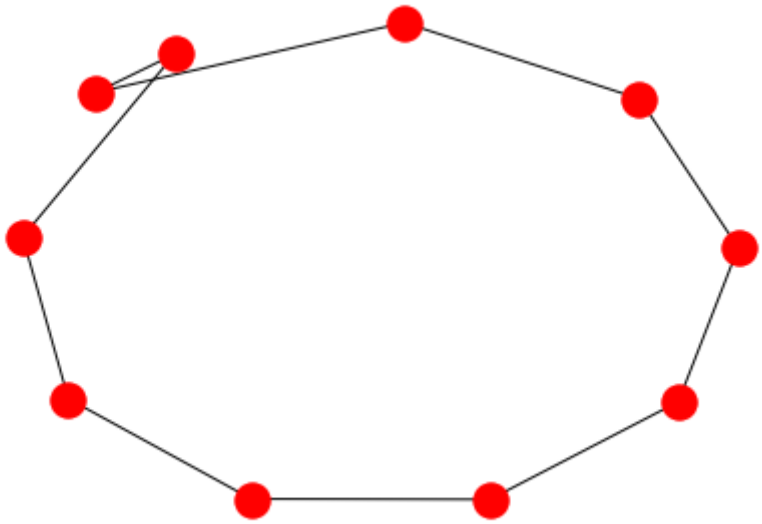

```
[[0 1 0 0 0 0 0 0 0 1]
 [1 0 1 0 0 0 0 0 0 0]
 [0 1 0 1 0 0 0 0 0 0]
 [0 0 1 0 1 0 0 0 0 0]
 [0 0 0 1 0 1 0 0 0 0]
 [0 0 0 0 1 0 1 0 0 0]
 [0 0 0 0 0 1 0 1 0 0]
 [0 0 0 0 0 0 1 0 1 0]
 [0 0 0 0 0 0 0 1 0 1]
 [1 0 0 0 0 0 0 0 1 0]]
```

# Determine the adjacency matrices of the following graphs

**(i) Complete graph $K_{10}$**

**(ii) Ladder graph $L_9$**

**(iii) Complete bi - partite graph $K_{4,6}$**

**(iv) Petersen Graph**

**(i)**

In [48]:

```
G = nx.complete_graph(10)
nx.draw(G)
plt.show()
X = nx.adj_matrix(G)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
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  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

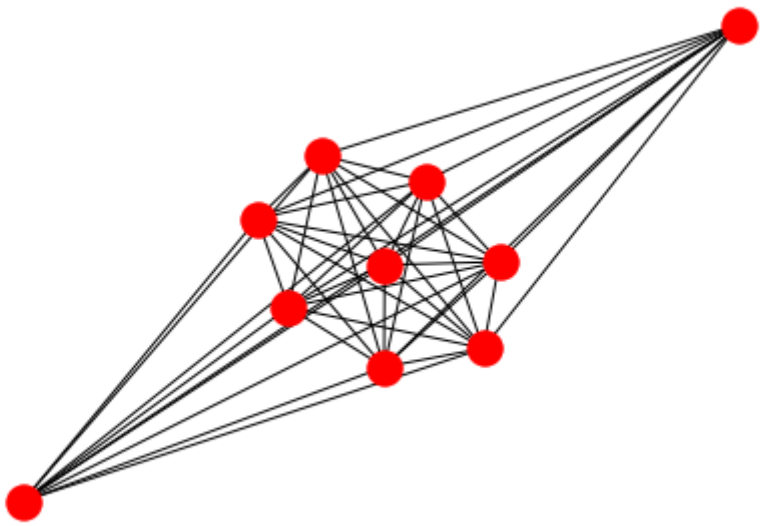

```
[[0 1 1 1 1 1 1 1 1 1]
 [1 0 1 1 1 1 1 1 1 1]
 [1 1 0 1 1 1 1 1 1 1]
 [1 1 1 0 1 1 1 1 1 1]
 [1 1 1 1 0 1 1 1 1 1]
 [1 1 1 1 1 0 1 1 1 1]
 [1 1 1 1 1 1 0 1 1 1]
 [1 1 1 1 1 1 1 0 1 1]
 [1 1 1 1 1 1 1 1 0 1]
 [1 1 1 1 1 1 1 1 1 0]]
```

# (ii)

In [52]:

```
g = nx.ladder_graph(9)
nx.draw(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
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  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

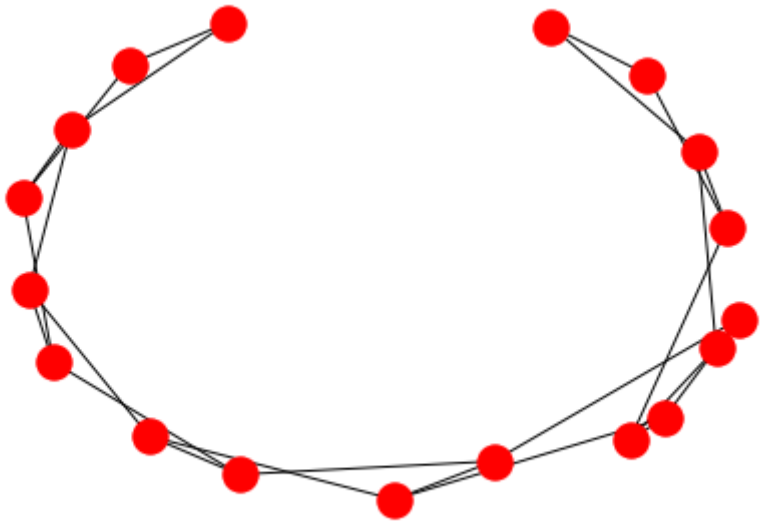

```
[[0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0]
 [1 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0]
 [0 1 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0]
 [0 0 1 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0]
 [0 0 0 1 0 1 0 0 0 0 0 0 0 1 0 0 0 0]
 [0 0 0 0 1 0 1 0 0 0 0 0 0 0 1 0 0 0]
 [0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 1 0 0]
 [0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 1 0]
 [0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1]
 [1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0]
 [0 1 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0]
 [0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0]
 [0 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 0 0]
 [0 0 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0 0]]
```

```
[0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 1 0 0]
[0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 1 0]
[0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 1]
[0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0]]
```

## (iii)

In [50]:

```
G = nx.complete_bipartite_graph(4,6)
nx.draw(G)
plt.show()
X = nx.adj_matrix(G)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
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  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

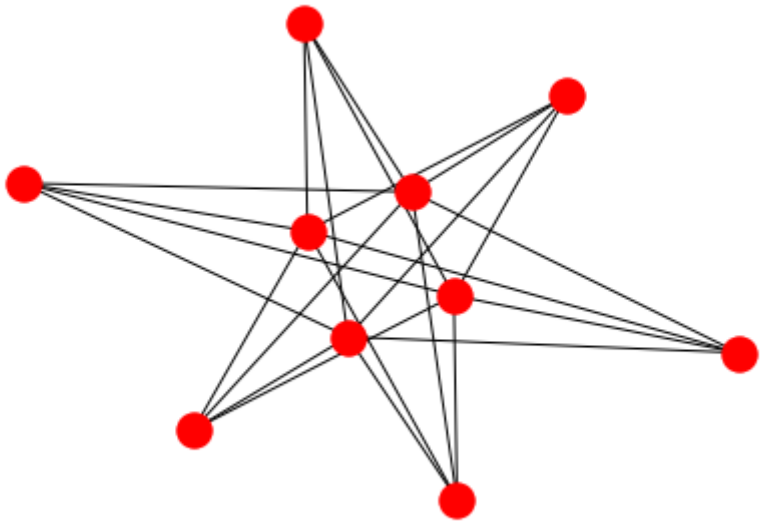

```
[[0 0 0 0 1 1 1 1 1 1]
 [0 0 0 0 1 1 1 1 1 1]
 [0 0 0 0 1 1 1 1 1 1]
 [0 0 0 0 1 1 1 1 1 1]
 [1 1 1 1 0 0 0 0 0 0]
 [1 1 1 1 0 0 0 0 0 0]
 [1 1 1 1 0 0 0 0 0 0]
 [1 1 1 1 0 0 0 0 0 0]
 [1 1 1 1 0 0 0 0 0 0]
 [1 1 1 1 0 0 0 0 0 0]]
```

# (iv)

In [51]:

```
G = nx.petersen_graph()
nx.draw(G)
plt.show()
X = nx.adj_matrix(G)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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d/or style files.
  warnings.warn(self.msg_depr_set % key)
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

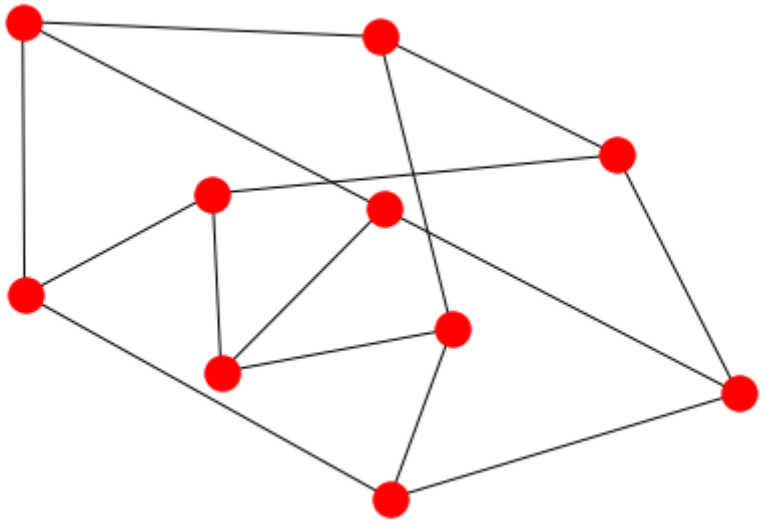

```
[[0 1 0 0 1 1 0 0 0 0]
 [1 0 1 0 0 0 1 0 0 0]
 [0 1 0 1 0 0 0 1 0 0]
 [0 0 1 0 1 0 0 0 1 0]
 [1 0 0 1 0 0 0 0 0 1]
 [1 0 0 0 0 0 0 1 1 0]
 [0 1 0 0 0 0 0 0 1 1]
 [0 0 1 0 0 1 0 0 0 1]
 [0 0 0 1 0 1 1 0 0 0]
 [0 0 0 0 1 0 1 1 0 0]]
```

In [72]:

```
n = 10
V = [(i,(i+1)%n) for i in range(n)]
V += [(i,(i+2)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
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C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

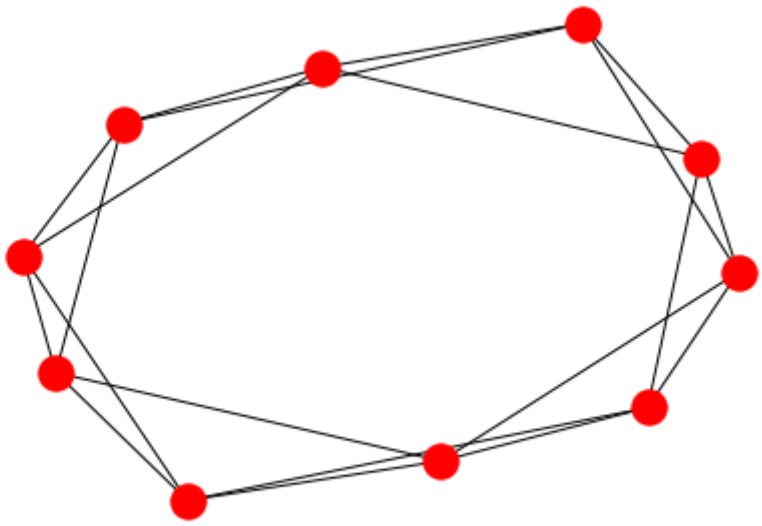

```
[[0 1 1 0 0 0 0 0 1 1]
 [1 0 1 1 0 0 0 0 0 1]
 [1 1 0 1 1 0 0 0 0 0]
 [0 1 1 0 1 1 0 0 0 0]
 [0 0 1 1 0 1 1 0 0 0]
 [0 0 0 1 1 0 1 1 0 0]
 [0 0 0 0 1 1 0 1 1 0]
```

```
 [0 0 0 0 0 1 1 0 1 1]
 [1 0 0 0 0 0 1 1 0 1]
 [1 1 0 0 0 0 0 1 1 0]]
```

In [85]:

```
G = nx.random_regular_graph(4,8)
nx.draw(G)
plt.show()
X = nx.adj_matrix(G)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

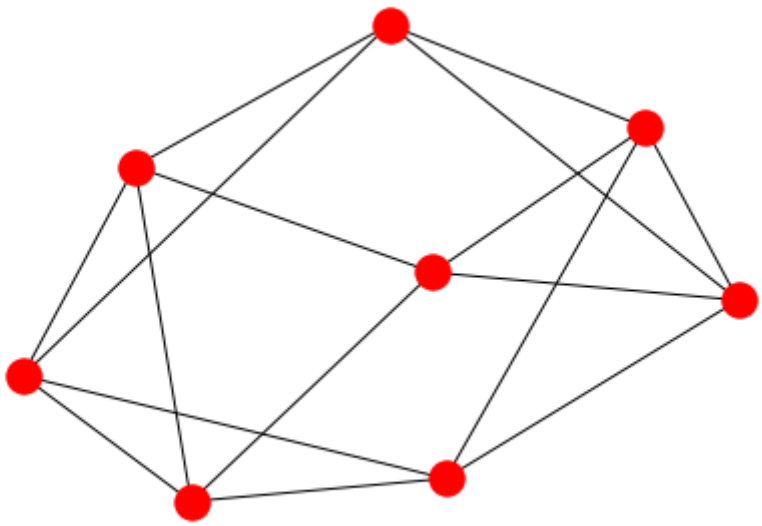

```
[[0 1 1 0 0 0 1 1]
 [1 0 1 0 1 1 0 0]
 [1 1 0 1 1 0 0 0]
 [0 0 1 0 1 0 1 1]
 [0 1 1 1 0 1 0 0]
 [0 1 0 0 1 0 1 1]
 [1 0 0 1 0 1 0 1]
 [1 0 0 1 0 1 1 0]]
```

# 11/02/2020

In [2]:

```
import networkx as nx
import matplotlib.pyplot as plt

n = 20
V = [(i,(i+1)%n) for i in range(n)]
V += [(i,(i+2)%n) for i in range(n)]
V += [(i,(i+3)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw_circular(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
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  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

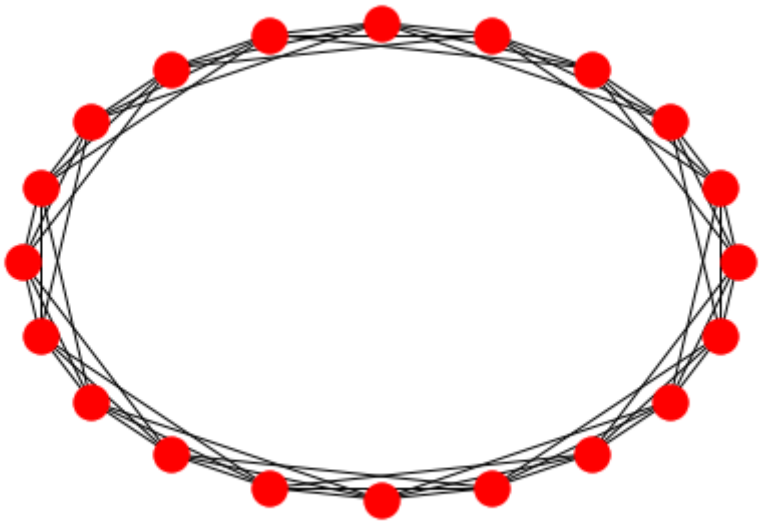

```
[[0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1]
 [1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1]
 [1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1]
 [1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0]
```

```
[0 0 0 0 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0]
[0 0 0 0 0 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0]
[0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 0 0 0 0 0]
[0 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 0 0 0 0]
[0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 0 0 0]
[0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 0 0]
[0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 0]
[0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0]
[0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 0]
[0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1]
[1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1]
[1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1]
[1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0]]
```

# Graph powers

**Let $G$ be a connected graph & $r$ be a positive integer. Then, $G^r$ is obtained by joining the vertices at a distance $\leq r$ by new edges.**

**Draw a cycle on 15 vertices and construct its 1st 5 powers. Also determine, the order and size of each of them.**

In [7]:

```
n = 15
V = [(i,(i+1)%n) for i in range(n)]
#V += [(i,(i+2)%n) for i in range(n)]
#V += [(i,(i+3)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw_circular(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

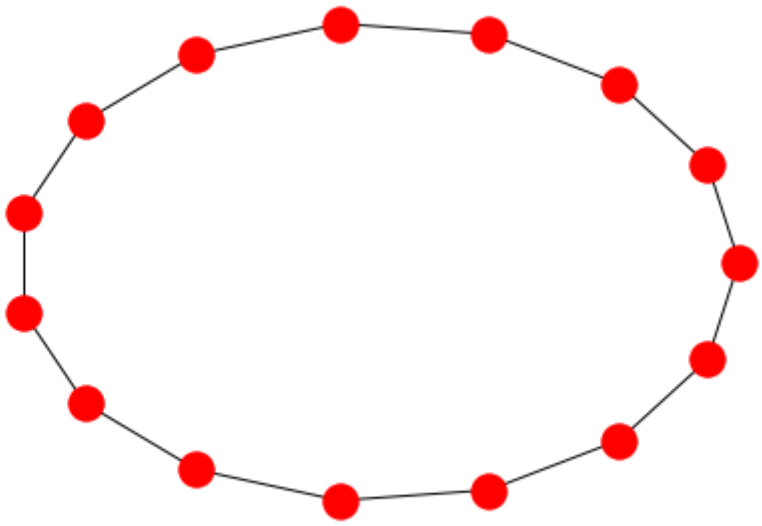

```
[[0 1 0 0 0 0 0 0 0 0 0 0 0 0 1]
 [1 0 1 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 1 0 1 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 1 0 1 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 1 0 1 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 1 0 1 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 1 0 1 0 0 0 0 0 0 0]
 [0 0 0 0 0 0 1 0 1 0 0 0 0 0 0]
 [0 0 0 0 0 0 0 1 0 1 0 0 0 0 0]
 [0 0 0 0 0 0 0 0 1 0 1 0 0 0 0]
 [0 0 0 0 0 0 0 0 0 1 0 1 0 0 0]
```

```
[0 0 0 0 0 0 0 0 0 1 0 1 0 0 0]
[0 0 0 0 0 0 0 0 0 0 1 0 1 0 0]
[0 0 0 0 0 0 0 0 0 0 0 1 0 1 0]
[0 0 0 0 0 0 0 0 0 0 0 0 1 0 1]
[1 0 0 0 0 0 0 0 0 0 0 0 0 1 0]]
```

In [8]:

```
n = 15
V = [(i,(i+1)%n) for i in range(n)]
V += [(i,(i+2)%n) for i in range(n)]
#V += [(i,(i+3)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw_circular(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

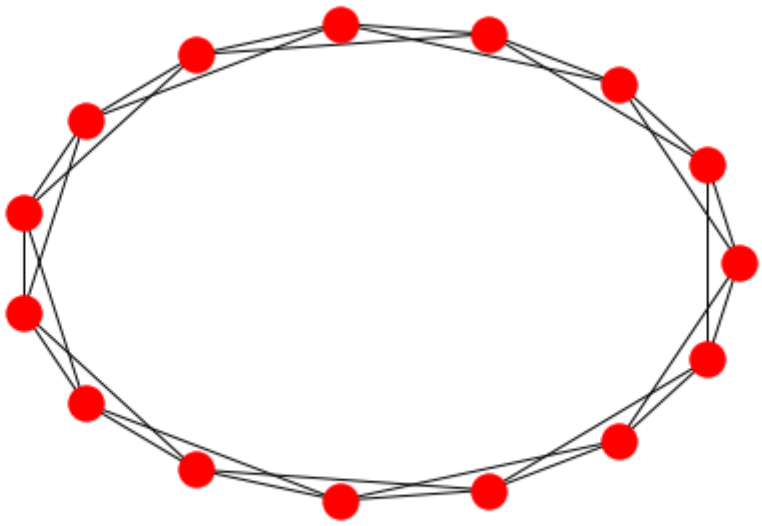

```
[[0 1 1 0 0 0 0 0 0 0 0 0 0 1 1]
 [1 0 1 1 0 0 0 0 0 0 0 0 0 0 1]
 [1 1 0 1 1 0 0 0 0 0 0 0 0 0 0]
 [0 1 1 0 1 1 0 0 0 0 0 0 0 0 0]
 [0 0 1 1 0 1 1 0 0 0 0 0 0 0 0]
 [0 0 0 1 1 0 1 1 0 0 0 0 0 0 0]
 [0 0 0 0 1 1 0 1 1 0 0 0 0 0 0]
 [0 0 0 0 0 1 1 0 1 1 0 0 0 0 0]
 [0 0 0 0 0 0 1 1 0 1 1 0 0 0 0]
 [0 0 0 0 0 0 0 1 1 0 1 1 0 0 0]]
```

```
[0 0 0 0 0 0 0 0 1 1 0 1 1 0 0]
[0 0 0 0 0 0 0 0 0 1 1 0 1 1 0]
[0 0 0 0 0 0 0 0 0 0 1 1 0 1 1]
[1 0 0 0 0 0 0 0 0 0 0 1 1 0 1]
[1 1 0 0 0 0 0 0 0 0 0 0 1 1 0]]
```

In [9]:

```
n = 15
V = [(i,(i+1)%n) for i in range(n)]
V += [(i,(i+2)%n) for i in range(n)]
V += [(i,(i+3)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw_circular(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
8: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
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  plt.hold(b)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\__init__.py:917: User
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d/or style files.
  warnings.warn(self.msg_depr_set % key)
C:\Users\Jeevan\Anaconda3\lib\site-packages\matplotlib\rcsetup.py:152: UserW
arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

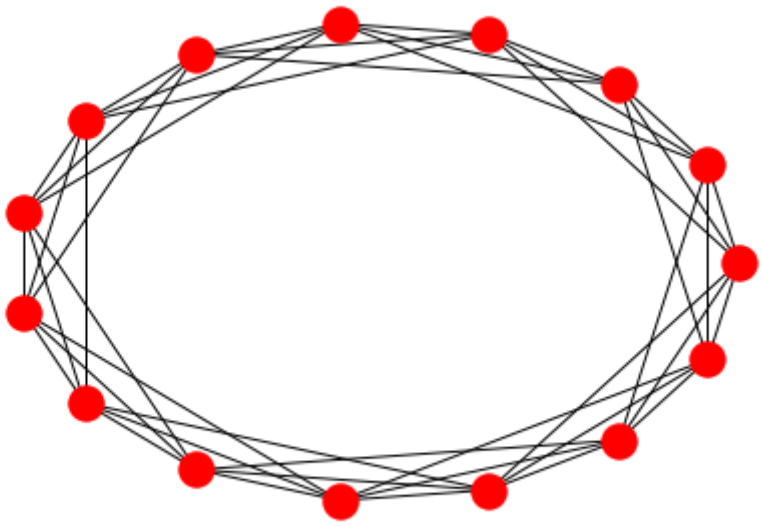

```
[[0 1 1 1 0 0 0 0 0 0 0 0 1 1 1]
 [1 0 1 1 1 0 0 0 0 0 0 0 0 1 1]
 [1 1 0 1 1 1 0 0 0 0 0 0 0 0 1]
 [1 1 1 0 1 1 1 0 0 0 0 0 0 0 0]
 [0 1 1 1 0 1 1 1 0 0 0 0 0 0 0]
 [0 0 1 1 1 0 1 1 1 0 0 0 0 0 0]
 [0 0 0 1 1 1 0 1 1 1 0 0 0 0 0]
 [0 0 0 0 1 1 1 0 1 1 1 0 0 0 0]
 [0 0 0 0 0 1 1 1 0 1 1 1 0 0 0]
 [0 0 0 0 0 0 1 1 1 0 1 1 1 0 0]]
```

```
[0 0 0 0 0 0 0 1 1 1 0 1 1 1 0]
[0 0 0 0 0 0 0 0 1 1 1 0 1 1 1]
[1 0 0 0 0 0 0 0 0 1 1 1 0 1 1]
[1 1 0 0 0 0 0 0 0 0 1 1 1 0 1]
[1 1 1 0 0 0 0 0 0 0 0 1 1 1 0]]
```

In [10]:

```
n = 15
V = [(i,(i+1)%n) for i in range(n)]
V += [(i,(i+2)%n) for i in range(n)]
V += [(i,(i+3)%n) for i in range(n)]
V += [(i,(i+4)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw_circular(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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  b = plt.ishold()
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
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arning: axes.hold is deprecated, will be removed in 3.0
  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

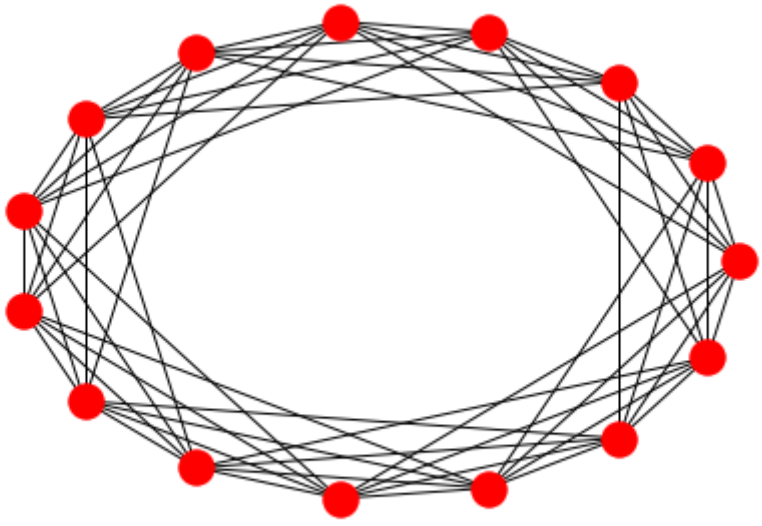

```
[[0 1 1 1 1 0 0 0 0 0 0 1 1 1 1]
 [1 0 1 1 1 1 0 0 0 0 0 0 1 1 1]
 [1 1 0 1 1 1 1 0 0 0 0 0 0 1 1]
 [1 1 1 0 1 1 1 1 0 0 0 0 0 0 1]
 [1 1 1 1 0 1 1 1 1 0 0 0 0 0 0]
 [0 1 1 1 1 0 1 1 1 1 0 0 0 0 0]
 [0 0 1 1 1 1 0 1 1 1 1 0 0 0 0]
 [0 0 0 1 1 1 1 0 1 1 1 1 0 0 0]
 [0 0 0 0 1 1 1 1 0 1 1 1 1 0 0]
```

```
[0 0 0 0 0 1 1 1 1 0 1 1 1 1 0]
[0 0 0 0 0 0 1 1 1 1 0 1 1 1 1]
[1 0 0 0 0 0 0 1 1 1 1 0 1 1 1]
[1 1 0 0 0 0 0 0 1 1 1 1 0 1 1]
[1 1 1 0 0 0 0 0 0 1 1 1 1 0 1]
[1 1 1 1 0 0 0 0 0 0 1 1 1 1 0]]
```

In [11]:

```
n = 15
V = [(i,(i+1)%n) for i in range(n)]
V += [(i,(i+2)%n) for i in range(n)]
V += [(i,(i+3)%n) for i in range(n)]
V += [(i,(i+4)%n) for i in range(n)]
V += [(i,(i+5)%n) for i in range(n)]
g = nx.Graph(V)
nx.draw_circular(g)
plt.show()
X = nx.adj_matrix(g)
print(X.todense())
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
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```

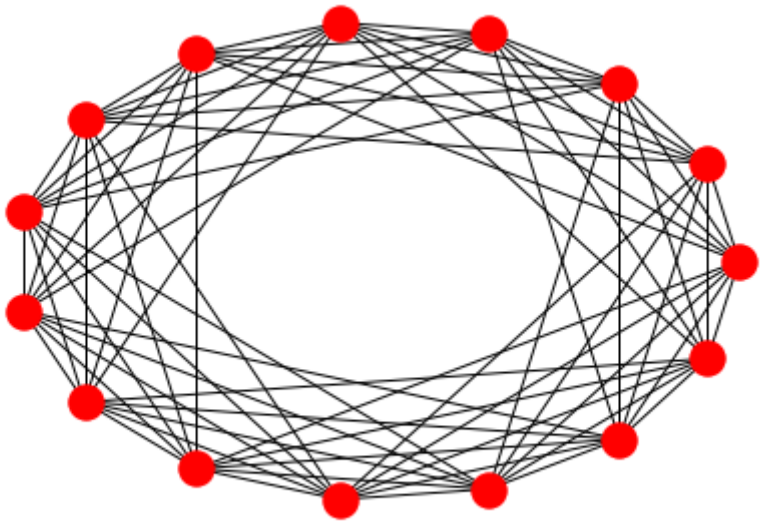

```
[[0 1 1 1 1 1 0 0 0 0 1 1 1 1 1]
 [1 0 1 1 1 1 1 0 0 0 0 1 1 1 1]
 [1 1 0 1 1 1 1 1 0 0 0 0 1 1 1]
 [1 1 1 0 1 1 1 1 1 0 0 0 0 1 1]
 [1 1 1 1 0 1 1 1 1 1 0 0 0 0 1]
 [1 1 1 1 1 0 1 1 1 1 1 0 0 0 0]
 [0 1 1 1 1 1 0 1 1 1 1 1 0 0 0]
 [0 0 1 1 1 1 1 0 1 1 1 1 1 0 0]
```

```
[0 0 0 1 1 1 1 1 0 1 1 1 1 1 0]
[0 0 0 0 1 1 1 1 1 0 1 1 1 1 1]
[1 0 0 0 0 1 1 1 1 1 0 1 1 1 1]
[1 1 0 0 0 0 1 1 1 1 1 0 1 1 1]
[1 1 1 0 0 0 0 1 1 1 1 1 0 1 1]
[1 1 1 1 0 0 0 0 1 1 1 1 1 0 1]
[1 1 1 1 1 0 0 0 0 1 1 1 1 1 0]]
```

**If, $d$ is the diameter of the graph, then, $G^d$, is a complete graph.**

## Construct the first few powers of the Petersen Graph & write the adjacency matrix of each of them.

In [13]:

```
g = nx.petersen_graph()
shells = [[5,6,7,8,9],[0,1,2,3,4]]
nx.draw_shell(g,nlist=shells,with_labels=True,node_size=100,node_color="violet")
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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    Axes and/or Figure.
  b = plt.ishold()
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  warnings.warn("axes.hold is deprecated, will be removed in 3.0")
```

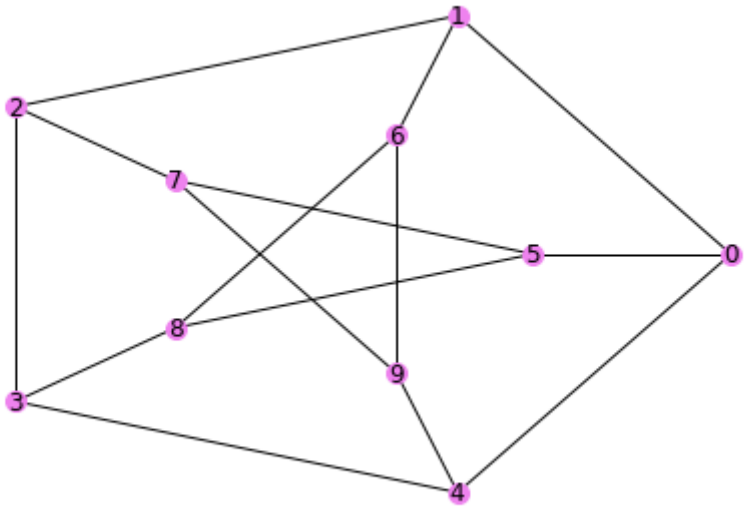


# WAP to construct graph powers.

In [17]:

```
def graphpow(n,p):
    import matplotlib.pyplot as plt
    import networkx as nx
    V = [(i,(i+1)%n) for i in range(n)]
    g = nx.Graph(V)
    nx.draw_circular(nx.power(g,p))
    plt.show()
    X = nx.adj_matrix(g)
    print(X.todense())
```

In [2]:

```
import networkx as nx
g = nx.cycle_graph(5)
X = nx.incidence_matrix(g)
print(X.todense())
```

```
[[1. 1. 0. 0. 0.]
 [1. 0. 1. 0. 0.]
 [0. 0. 1. 1. 0.]
 [0. 0. 0. 1. 1.]
 [0. 1. 0. 0. 1.]]
```

In [18]:

```
n = int(input("Enter the number of vertices: "))
p = int(input("Enter the power: "))
graphpow(n,p)
```

```
Enter the number of vertices: 15
Enter the power: 5
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
    plot commands add elements without first clearing the
    Axes and/or Figure.
  b = plt.ishold()
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  plt.hold(b)
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```

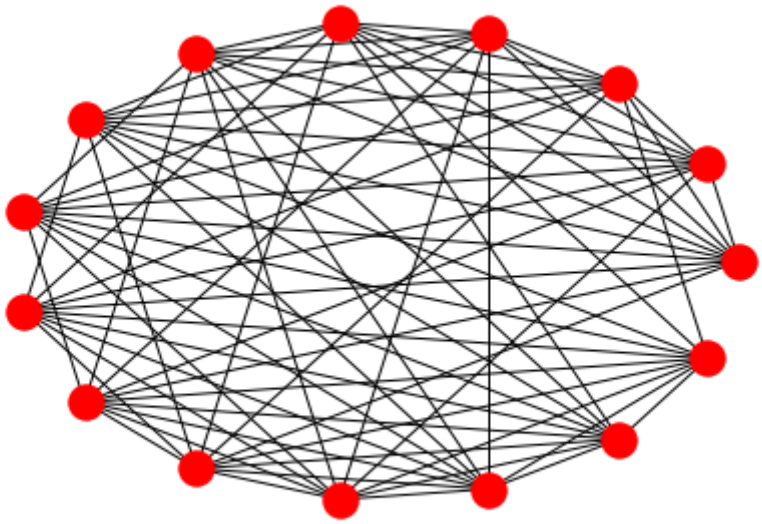

```
[[0 1 0 0 0 0 0 0 0 0 0 0 0 0 1]
 [1 0 1 0 0 0 0 0 0 0 0 0 0 0 0]
 [0 1 0 1 0 0 0 0 0 0 0 0 0 0 0]
 [0 0 1 0 1 0 0 0 0 0 0 0 0 0 0]
 [0 0 0 1 0 1 0 0 0 0 0 0 0 0 0]
 [0 0 0 0 1 0 1 0 0 0 0 0 0 0 0]
 [0 0 0 0 0 1 0 1 0 0 0 0 0 0 0]
 [0 0 0 0 0 0 1 0 1 0 0 0 0 0 0]
 [0 0 0 0 0 0 0 1 0 1 0 0 0 0 0]
 [0 0 0 0 0 0 0 0 1 0 1 0 0 0 0]
 [0 0 0 0 0 0 0 0 0 1 0 1 0 0 0]
 [0 0 0 0 0 0 0 0 0 0 1 0 1 0 0]
 [0 0 0 0 0 0 0 0 0 0 0 1 0 1 0]
 [0 0 0 0 0 0 0 0 0 0 0 0 1 0 1]
 [1 0 0 0 0 0 0 0 0 0 0 0 0 1 0]]
```

```
 [0 0 0 0 0 0 0 0 0 0 0 0 1 0 1]
 [1 0 0 0 0 0 0 0 0 0 0 0 0 1 0]]
```

In [ ]:

```
```

# Algorithms

In [3]:

```
import networkx as nx
import matplotlib.pyplot as ply
```

In [10]:

```
G = nx.Graph()
e = [('a','b',0.3),('b','c',0.9),('a','c',0.5),('c','d',1.2)]
G.add_weighted_edges_from(e)
print(nx.dijkstra_path(G,'a','d'))
labels = nx.get_edge_attributes(G,'weight')
nx.draw(G,with_labels=True)
ply.show()
```

```
['a', 'c', 'd']
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:13
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```

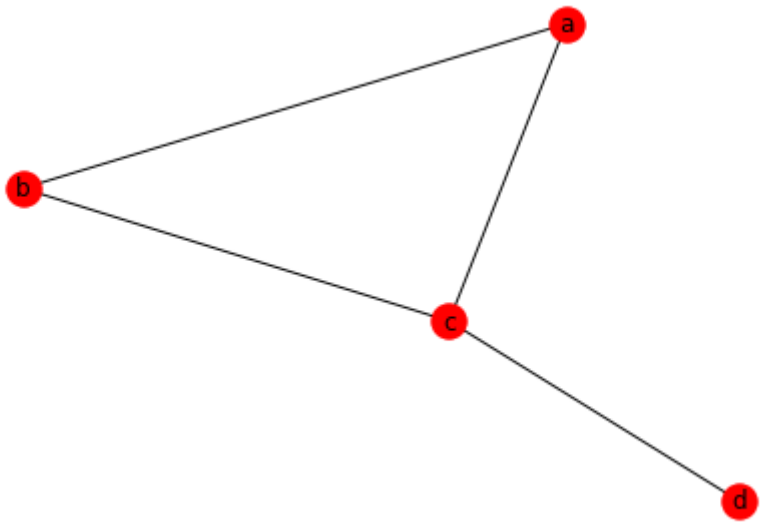


## The bipartite algorithms are not imported into the networkx namespace at the top level so the easiest way to use them is with "from networkx.algorithms import bipartite".

In [11]:

```
from networkx.algorithms import bipartite
```

In [14]:

```
B = nx.Graph()
B.add_nodes_from([1,2,3,4],bipartite=0)
B.add_nodes_from(['a','b','c'],bipartite=1)
B.add_edges_from([(1,'a'),(1,'b'),(2,'b'),(2,'c'),(3,'c'),(4,'a')])
nx.draw(B,with_labels=True)
ply.show()
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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```

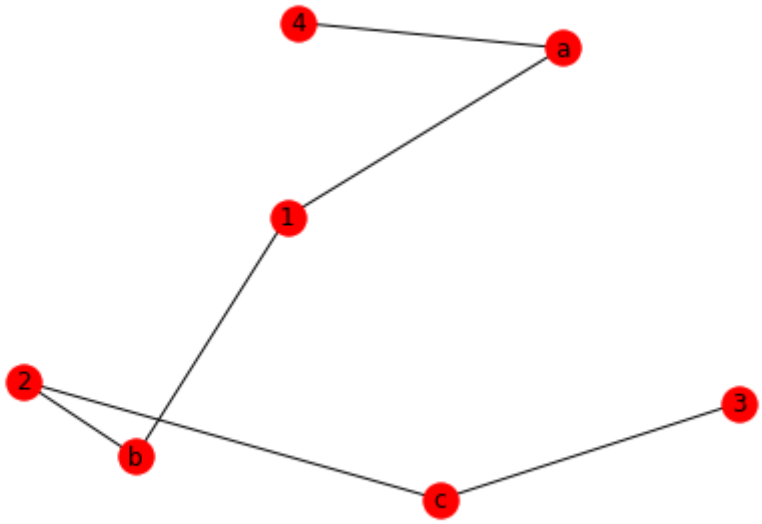


In [15]:

```
nx.is_connected(B)
```

Out[15]:

True

# Prepare a bipartite graph, with 4 vertices in 1 partition & 6 vertices in the 2nd partition and 20 edges. Check whether this bipartite

# graph is connected.

In [18]:

```
B = nx.Graph()
B.add_nodes_from([1,2,3,4],bipartite=0)
B.add_nodes_from(['a','b','c','d','e','f'],bipartite=1)
B.add_edges_from([(1,'a'),(1,'b'),(1,'c'),(1,'d'),(1,'e'),(1,'f'),
                  (2,'b'),(2,'c'),
                  (3,'a'),(3,'b'),(3,'c'),(3,'d'),(3,'e'),(3,'f'),
                  (4,'a'),(4,'b'),(4,'c'),(4,'d'),(4,'e'),(4,'f')])
nx.draw(B,with_labels=True)
ply.show()
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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```

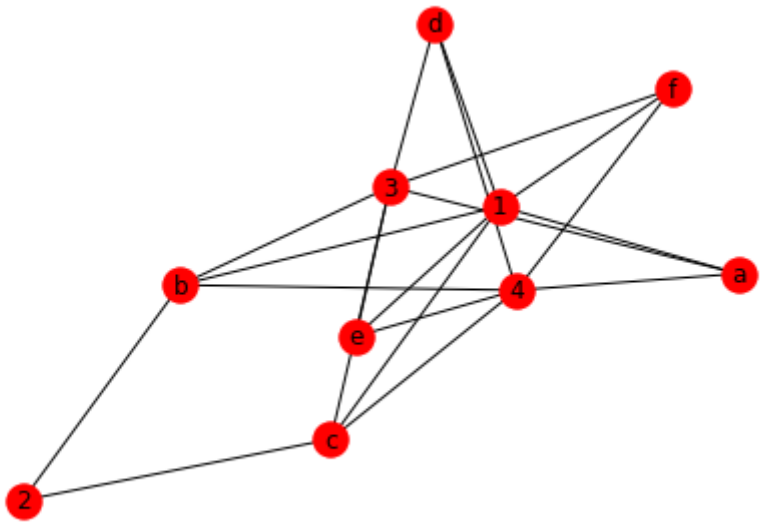


In [19]:

```
nx.is_connected(G)
```

Out[19]:

True

In [21]:

```
G = nx.Graph()
e = [('a','b',9),('a','c',3),('a','d',7),('a','s',2),
    ('b','d',4),('b','t',7),
    ('s','c',4),
    ('c','d',5),
    ('d','t',9)]
G.add_weighted_edges_from(e)
print(nx.dijkstra_path(G,'s','t'))
labels = nx.get_edge_attributes(G,'weight')
nx.draw(G,with_labels=True)
ply.show()
```

```
['s', 'a', 'd', 't']
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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  b = plt.ishold()
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```

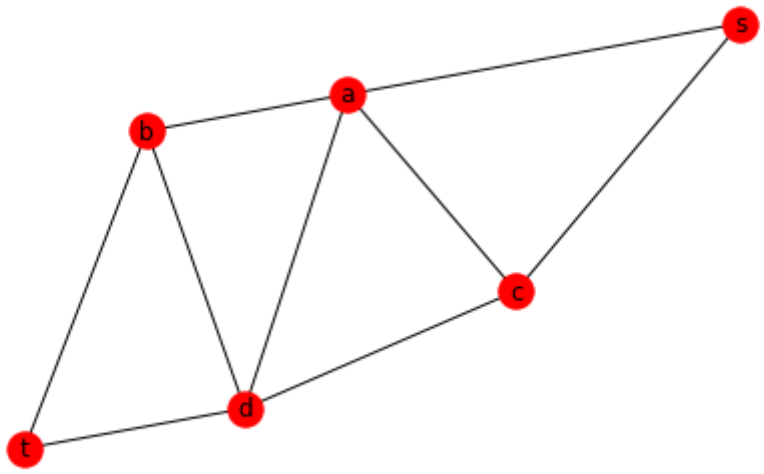

In [22]:

```
G = nx.path_graph(4)
X,Y = bipartite.sets(G)
list(X)
```

Out[22]:

```
[0, 2]
```

In [23]:

```
list(Y)
```

Out[23]:

```
[1, 3]
```

In [30]:

```
G = nx.complete_graph(9)
nx.is_eulerian(G)
nx.draw(G,with_labels=True)
ply.show()
list(nx.eulerian_circuit(G))
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
    Future behavior will be consistent with the long-time default:
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```

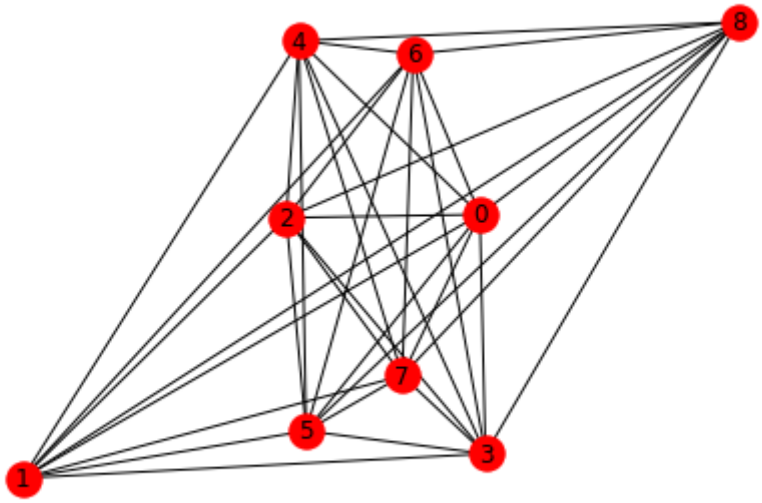


Out[30]:

```
[(0, 8),
 (8, 7),
 (7, 6),
 (6, 8),
 (8, 5),
 (5, 7),
 (7, 4),
 (4, 6),
 (6, 5),
 (5, 4),
 (4, 8),
 (8, 3),
```

```
 (3, 7),
 (7, 2),
 (2, 6),
 (6, 3),
 (3, 5),
 (5, 2),
 (2, 4),
 (4, 3),
 (3, 2),
 (2, 8),
 (8, 1),
 (1, 7),
 (7, 0),
 (0, 6),
 (6, 1),
 (1, 5),
 (5, 0),
 (0, 4),
 (4, 1),
 (1, 3),
 (3, 0),
 (0, 2),
 (2, 1),
 (1, 0)]
```

In [27]:

```
P = nx.petersen_graph()
nx.is_eulerian(P)
```

Out[27]:

```
False
```

In [28]:

```
D = nx.dodecahedral_graph()
nx.is_eulerian(D)
```

Out[28]:

```
False
```

In [31]:

```
list(nx.eulerian_circuit(G,source=1))
```

Out[31]:

```
[(1, 8),
 (8, 7),
 (7, 6),
 (6, 8),
 (8, 5),
 (5, 7),
 (7, 4),
 (4, 6),
 (6, 5),
 (5, 4),
 (4, 8),
 (8, 3),
 (3, 7),
 (7, 2),
 (2, 6),
 (6, 3),
 (3, 5),
 (5, 2),
 (2, 4),
 (4, 3),
 (3, 2),
 (2, 8),
 (8, 0),
 (0, 7),
 (7, 1),
 (1, 6),
 (6, 0),
 (0, 5),
 (5, 1),
 (1, 4),
 (4, 0),
 (0, 3),
 (3, 1),
 (1, 2),
 (2, 0),
 (0, 1)]
```

In [33]:

```
nx.draw(G,with_labels=True)
ply.show()
```

```
C:\Users\Jeevan\Anaconda3\lib\site-packages\networkx\drawing\nx_pylab.py:12
6: MatplotlibDeprecationWarning: pyplot.hold is deprecated.
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```

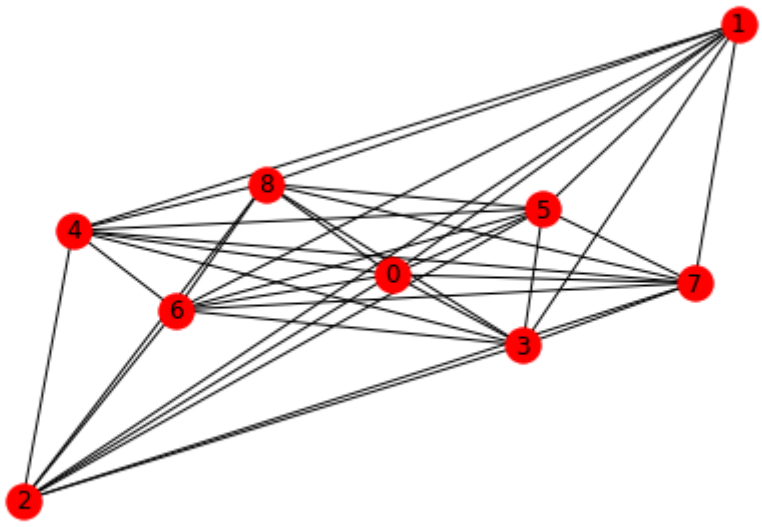

In [34]:

```
sp = dict(nx.all_pairs_shortest_path(G))
sp[3]
```

Out[34]:

```
{0: [3, 0],
 1: [3, 1],
 2: [3, 2],
 3: [3],
 4: [3, 4],
 5: [3, 5],
 6: [3, 6],
 7: [3, 7],
 8: [3, 8]}
```

In [35]:

```
sp = dict(nx.all_pairs_shortest_path(G))
sp[1]
```

Out[35]:

```
{0: [1, 0],
 1: [1],
 2: [1, 2],
 3: [1, 3],
 4: [1, 4],
 5: [1, 5],
 6: [1, 6],
 7: [1, 7],
 8: [1, 8]}
```

In [ ]:

```

```