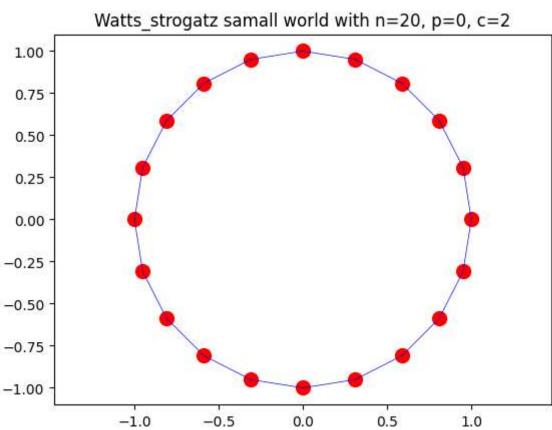
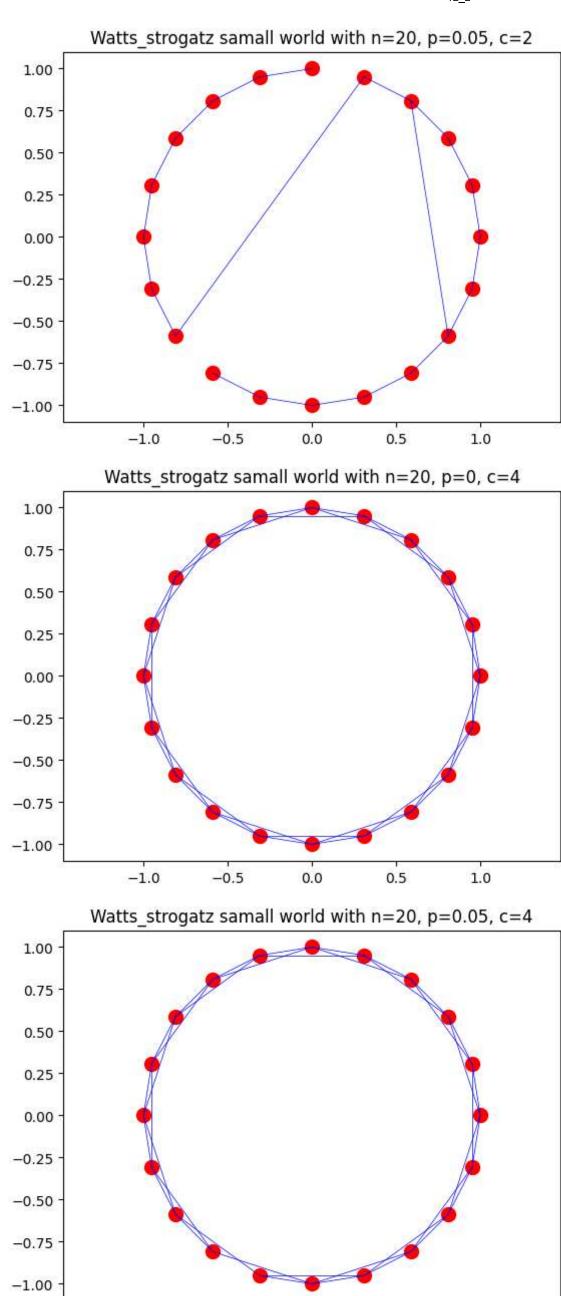
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12.2.a

```
In [ ]: import numpy as np
import matplotlib.pyplot as plt
def watts_strogatz_graph(n, k, p):
    G = np.zeros((n, n), dtype=int)
    for i in range(n):
        for j in range(1, k // 2 + 1):
            G[i, (i + j) % n] = 1
            G[i, (i - j) % n] = 1
    for i in range(n):
        for j in range(n):
            if G[i, j] == 1 and np.random.rand() < p:</pre>
                 G[i, j] = 0
                 rand_node = np.random.randint(0, n - 1)
                 while rand node == i or G[i, rand node] == 1:
                     rand_node = np.random.randint(0, n - 1)
                 G[i, rand\_node] = 1
    return G
def plot_graph_circular(G):
    angles = np.linspace(0, 2 * np.pi, G.shape[0], endpoint=False)
    positions = np.column_stack([np.cos(angles), np.sin(angles)])
    plt.figure()
    for i in range(G.shape[0]):
        for j in range(i + 1, G.shape[0]):
             if G[i, j] == 1:
                 plt.plot([positions[i, 0], positions[j, 0]], [positions[i, 1], positions[j, 1]], color='blue', linew:
    plt.scatter(positions[:, 0], positions[:, 1], c='red', s=100)
    plt.axis('equal')
    plt.title(f'Watts_strogatz samall world with n=\{n\}, p=\{p\}, c=\{c\}')
    plt.show()
n = 20
c_{list} = [2,4,8]
p_{list} = [0,0.05]
for c in c_list:
    for p in p_list:
        ws_graph = watts_strogatz_graph(n, c, p)
        plot_graph_circular(ws_graph)
```



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0.5

1.0

0.0

-1.0

-0.5

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