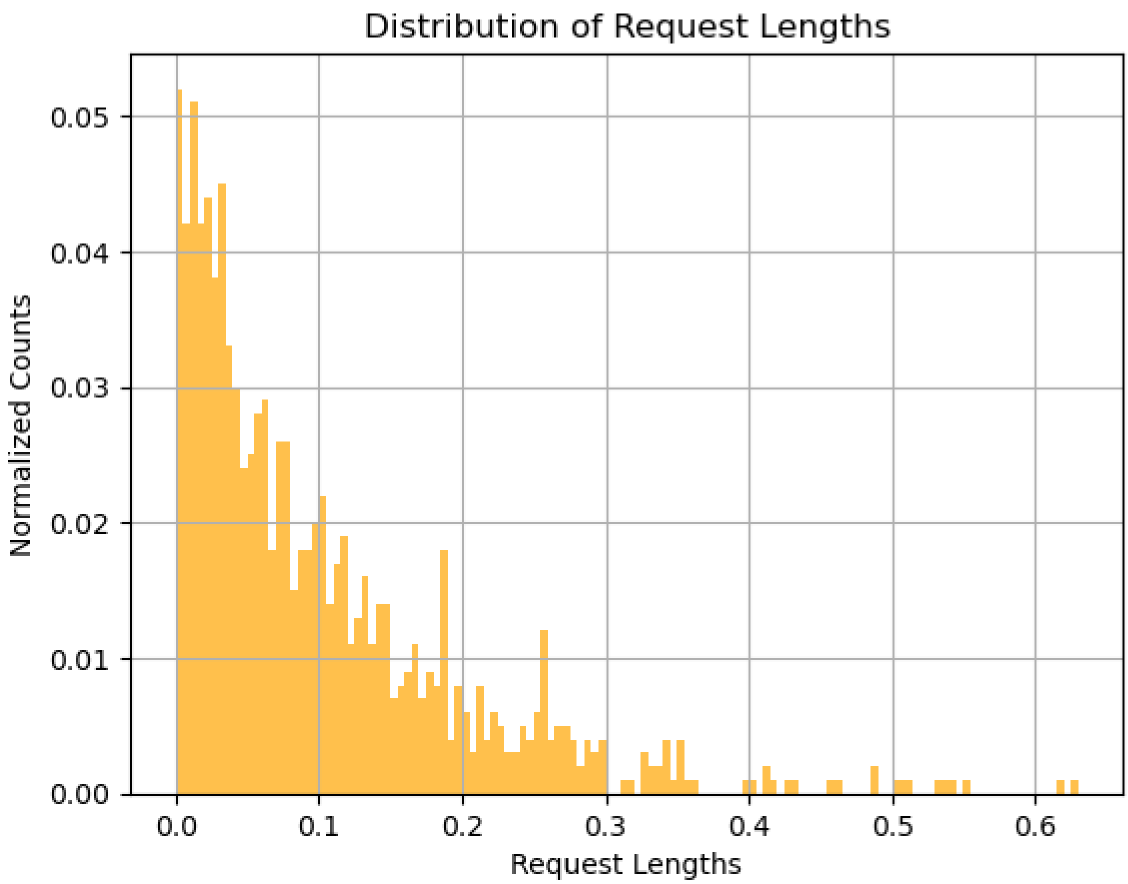
Problem 1

In [ ]:
```
import csv
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from scipy.stats import norm
from scipy.stats import uniform
import math
```

In [ ]:
```
path = '/Users/jidali/cs350/assignment/hw2_src/src/build/server_mt-output.txt'
request_lengths = []
sent_tscs = []
with open(path, 'r') as file:
    for line in file:
        if line[0] == 'R':
            ls = line.split(',')
            sent_tsc = (float)(ls[0].split(':')[1])
            sent_tscs.append(sent_tsc)
            request_len = (float)(ls[1])
            request_lengths.append(request_len)

# print(sent_tscs)
```

a) The distribution plot of request lengths

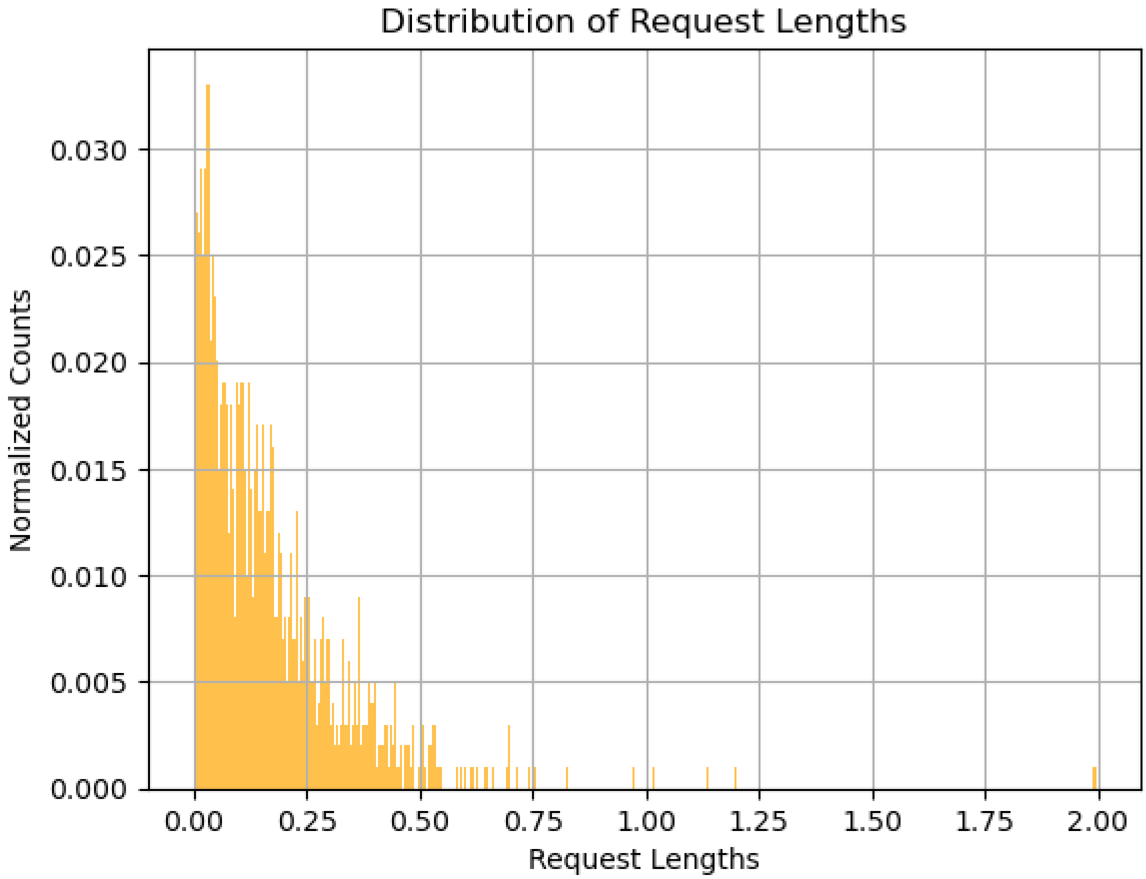
In [ ]:
```
req_lens = np.zeros(1000)
for i in range(0, 1000):
    req_lens[i] = request_lengths[i]


bins_a = np.arange(0, np.max(req_lens)+0.005, 0.005)
counts_a, _ = np.histogram(req_lens, bins=bins_a)
percentage_counts_a = counts_a / 1000.0
plt.bar(bins_a[:-1], percentage_counts_a, width=0.005, align='edge', alpha=0.7,

plt.xlabel('Request Lengths')
plt.ylabel('Normalized Counts')
plt.title('Distribution of Request Lengths')
plt.grid(True)
plt.show()
```



b) The distribution plot of inner-arrival time

In [ ]:

```
inner_times = np.zeros(999)
for i in range(len(sent_tscs)-1):
    inner_time = sent_tscs[i+1] - sent_tscs[i]
    inner_times[i] = inner_time

bins_b = np.arange(0, np.max(inner_times)+0.005, 0.005)
counts_b, _ = np.histogram(inner_times, bins=bins_b)
percentage_counts_b = counts_b / 999.0
plt.bar(bins_b[:-1], percentage_counts_b, width=0.005, align='edge', alpha=0.7,

plt.xlabel('Request Lengths')
plt.ylabel('Normalized Counts')
plt.title('Distribution of Request Lengths')
plt.grid(True)
plt.show()
# print(np.max(inner_times))
# print(inner_times)
```

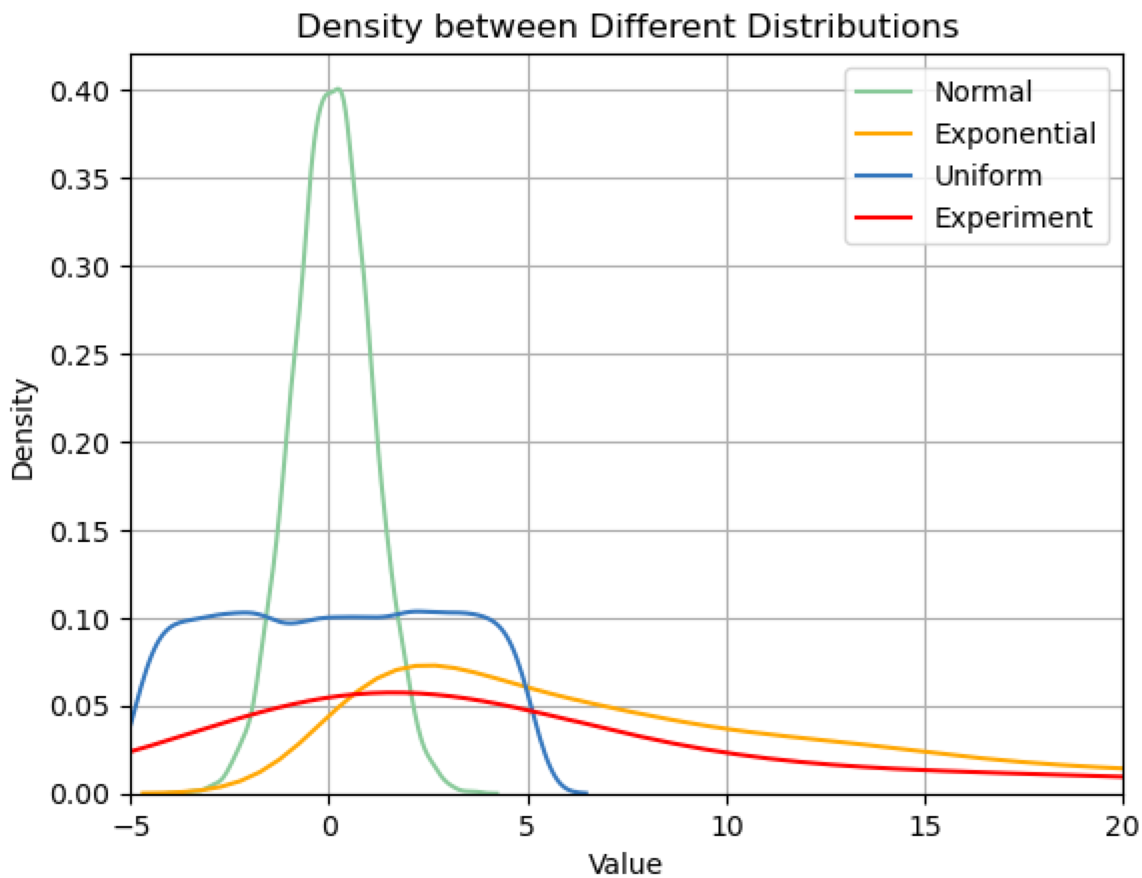


c) Reverse-engineer

The distribution of request lengths matches the exponential distribution.

In [ ]:

```
normal_samples = np.random.normal(1/10, 1, 10000)
exponential_samples = np.random.exponential(10, 10000)
uniform_samples = np.random.uniform(0.1-5, 0.1+5, 10000)

# Use kdeplot to plot the kernel density estimate
sns.kdeplot(normal_samples, color='#88c999', label='Normal')
sns.kdeplot(exponential_samples, color='#ffa600', label='Exponential')
sns.kdeplot(uniform_samples, color='#3376BD', label='Uniform')
sns.kdeplot(counts_a, color='red', label='Experiment')

plt.title("Density between Different Distributions")
plt.xlabel("Value")
plt.ylabel("Density")
plt.grid(True)
plt.legend()
plt.xlim(-5, 20)
plt.show()
```



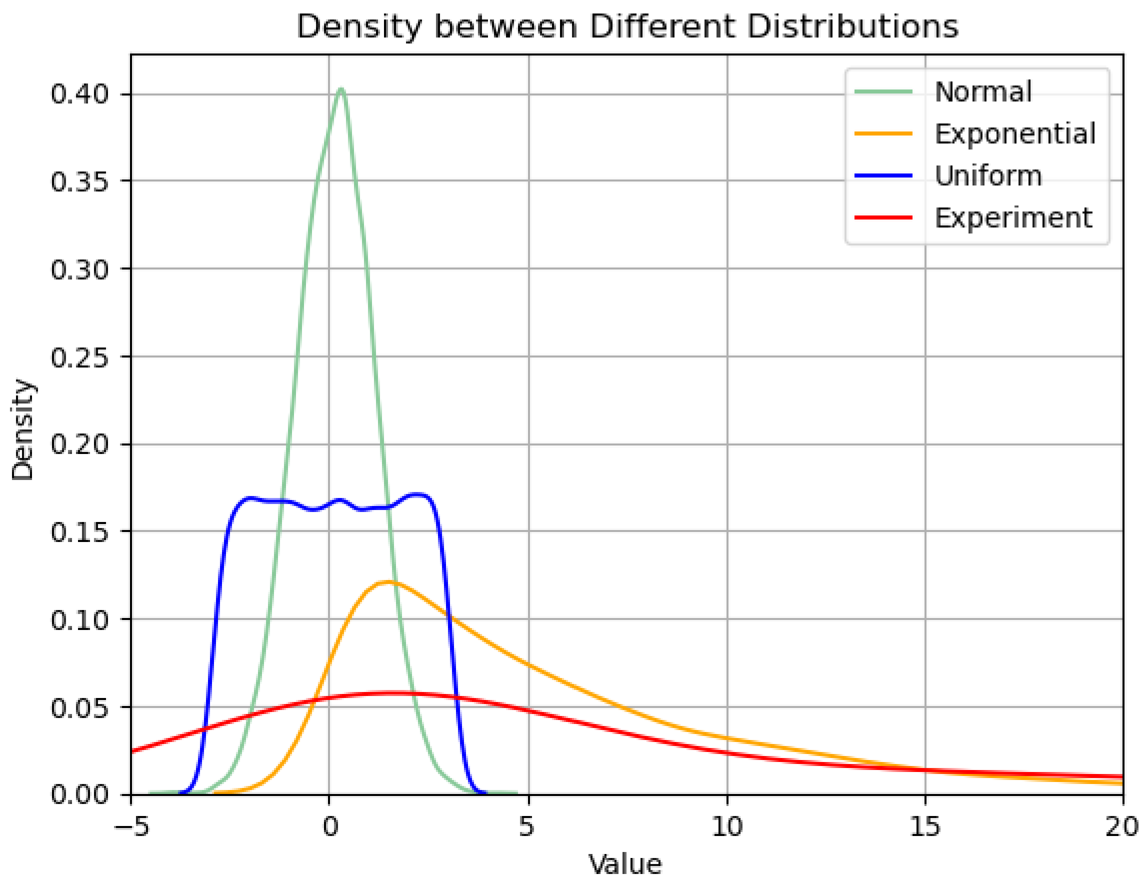
d)

The distribution of inner-arrival time does not match any distribution.

-a parameter is the request rate where $\lambda =$

-s parameter is the service rate where $T_s = \frac{1}{\mu}$

In [ ]:
```
normal_samples = np.random.normal(1/6, 1, 10000)
exponential_samples = np.random.exponential(6, 10000)
uniform_samples = np.random.uniform(0.1-3, 0.1+3, 10000)

# Use kdeplot to plot the kernel density estimate
sns.kdeplot(normal_samples, color='#88c999', label='Normal')
sns.kdeplot(exponential_samples, color='orange', label='Exponential')
sns.kdeplot(uniform_samples, color='blue', label='Uniform')
sns.kdeplot(counts_a, color='red', label='Experiment')

plt.title("Density between Different Distributions")
plt.xlabel("Value")
plt.ylabel("Density")
plt.grid(True)
plt.legend()
plt.xlim(-5, 20)
plt.show()
```



Problem 2

In [ ]:

```
# Read the file
def avg_queue(path):
    with open(path, 'r') as file:
        lines = file.readlines()

    # Extract timestamps and queue lengths
    timestamps = []
    queue_lengths = []

    for line in lines:
        if line.startswith("R"):
            parts = line.split(',')
            timestamp = float(parts[0].split(':')[1])
            timestamps.append(timestamp)

            # Find the next Q: line
            idx = lines.index(line) + 1
            while not lines[idx].startswith("Q:"):
                idx += 1
            queue = lines[idx].split(':')[1].strip()
            if queue == "[]":
                queue_lengths.append(0)
            else:
                queue_lengths.append(len(queue.split(',')))

    # Compute time-weighted average
    total_time = timestamps[-1] - timestamps[0]
```

```
    weighted_sum = 0

    for i in range(1, len(timestamps)):
        delta_time = timestamps[i] - timestamps[i-1]
        weighted_sum += queue_lengths[i-1] * delta_time

    average_queue_length = weighted_sum / total_time
    # print("Time-weighted average queue length:", average_queue_length)
    return average_queue_length
```

a) Average queue length

In [ ]:
```
path = '/Users/jidali/cs350/assignment/hw2_src/src/build/server_q-output.txt'
print(f'The average queue length is: {avg_queue(path)}')
```

```
The average queue length is: 7.843221023564421
```

In [ ]:
```
def get_data(path):
    maxN = 0.0
    minN = 100.0
    mean = 0
    sum = 0
    var = 0
    std = 0
    response_ls = []
    with open(path, 'r') as file:
        for line in file:
            if line.startswith('R'):
                line = line.split(':')[1].split(',')
                response_time = (float)(line[4])-(float)(line[0])
                response_ls.append(response_time)
                sum += response_time

                maxN = max(maxN, response_time)
                minN = min(minN, response_time)
        mean = sum / len(response_ls)

        for t in response_ls:
            var += (t - mean)**2/len(response_ls)
        std = math.sqrt(var)

    return [maxN, minN, mean, std]

def get_reqlen(path):
    req_lens = np.zeros(1000)
    sent_tscs = []
    with open(path, 'r') as file:
        for line in file:
            if line[0] == 'R':
                ls = line.split(',')
                sent_tsc = (float)(ls[0].split(':')[1])
                sent_tscs.append(sent_tsc)
                request_len = (float)(ls[1])
                req_lens.append(request_len)
    return [req_lens, sent_tscs]

def get_inner(path, sent_tscs):
    inner_times = np.zeros(999)
    for i in range(len(sent_tscs)-1):
```

```
        inner_time = sent_tscs[i+1] - sent_tscs[i]
        inner_times[i] = inner_time

def computer_utilization(path):
    busy_time = 0
    total_time = 0
    with open(path, 'r') as file:
        rowNum = 0
        for line in file:
            if line.startswith('R'):
                line = line.split(':')[1].split(',')
                if rowNum == 0:
                    total_time -= (float)(line[3])
                    # print(f's: {line[3]}')
                elif rowNum == 999:
                    total_time += (float)(line[4])
                    # print(f'e: {line[4]}')
                busy_time += (float)(line[4]) - (float)(line[3])
                rowNum+=1
    return busy_time / total_time

def computer_all_utilization(start_index, end_index):
    all_utilization = []
    for i in range(start_index, end_index+1):
        path = f"./s{i}.txt"
        data = computer_utilization(path)
        all_utilization.append(data)
    return all_utilization

def get_all_response_avg(i, j):
    mean = 0
    all_means = []
    for i in range(i, j+1):
        path = f"./s{i}.txt"
        mean = get_data(path)[2]
        all_means.append(mean)
    return all_means

def get_avg_qlens(i, j):
    all_qlens = []
    for i in range(i, j+1):
        path = f"./s{i}.txt"
        mean = avg_queue(path)
        all_qlens.append(mean)
    return all_qlens
```

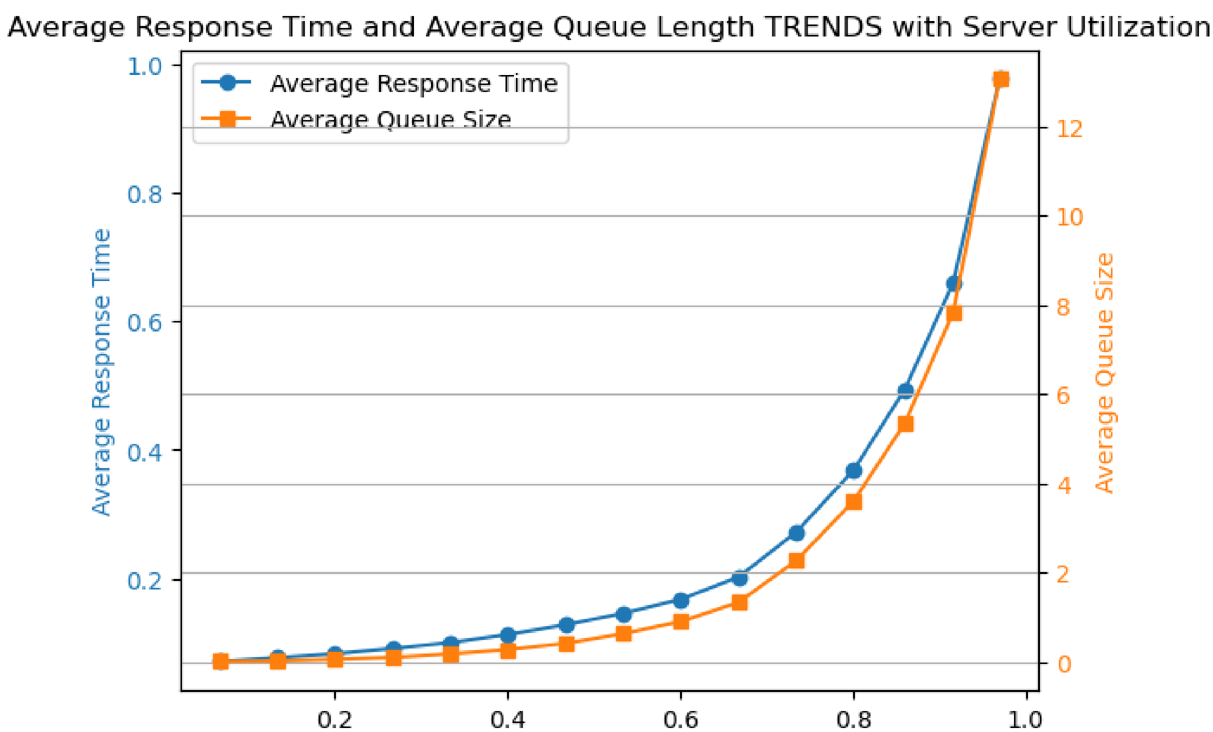
b)

As utilization increases, both response time and queue length averages increase proportionally.

In [ ]:

```
utili = computer_all_utilization(1,15)
# print(utili)
resp_ts = get_all_response_avg(1,15)
# print(resp_ts)
avg_qlens = get_avg_qlens(1, 15)

fig,ax1 = plt.subplots()
```

```
color = 'tab:blue'
ax1.set_ylabel('Average Response Time', color=color)
line1, = ax1.plot(utili,resp_ts,marker='o', color=color,label='Average Response
ax1.tick_params(axis='y', labelcolor=color)

ax2 = ax1.twinx()
color = 'tab:orange'
ax2.set_ylabel('Average Queue Size',color=color)
line2, = ax2.plot(utili,avg_qlens, marker='s' ,color=color,label='Average Queue
ax2.tick_params(axis='y',labelcolor=color)
plt.grid(True)
ax1.legend([line1, line2], ['Average Response Time', 'Average Queue Size'])

plt.title('Average Response Time and Average Queue Length TRENDS with Server Ut
plt.show()
```



c)

The response time and queue length increase proportionally with increasing utilization. To illustrate, by Little's Law, the Average Request Number = Arrival Rate times Average Response Time. As we assume there would always be one request running in the server, we can conclude that Average Request Number as the one of Average Queue Length.

```
In [ ]:
```