Exercise 1

Q Learning Algorithm:-

It is a reinforcement learning algorithm and does not require any environment of model. It is an iterative process updates model in the while exploration[1].

$$Q(s,a) = (1-\propto) * Q(s,a) + \propto * (r + \gamma * max_{a'} Q(s',a'))$$

Where,

Q(s,a) here Q table stores the reward for the particular position

$\propto$ it is learning rate

r is the rewards

γ it is discount factor

s it is the present position

a' it is the action

Code:

```
import gymnasium as gym
import random
import numpy as np
from os import system, name
from time import sleep
import pygame
import sys
import matplotlib.pyplot as plt
import time
```

Explanation:

1) First install the gymnasium, numpy, pygame, matplotlib, sys, time

```
class QAlgorithm:
    def __init__(self):
        self.env =  gym.make("Taxi-v3",render_mode="rgb_array")

        self.Qtable = np.zeros([self.env.observation_space.n,
self.env.action_space.n])
```

```
        self.number_of_training_episodes = 5000

        self.alpha = 0.1
        self.gamma = 0.6
        self.epsilon = 0.1
        self.Q_reward_array=[]
```

Explanation:-

Initializing the variable and giving values

Setting alpha as 0.1

Gamma as 0.6

Epsilon as 0.1

And created array of rewards

And making number of episodes of 5000

Training :-

```
    def Qtraining(self):
        for i in range(self.number_of_training_episodes):
            self.position = self.env.reset()[0]
            self.completed = False
            self.Q_reward =  0
            self.total_reward=0
            while not self.completed:
                if random.uniform(0, 1) < self.epsilon:
                    self.activity = self.env.action_space.sample()
                else:
                    self.activity =
np.argmax(self.Qtable[self.position])

                self.next_position, self.Q_reward, self.completed,_,_ =
self.env.step(self.activity)

                self.old_value = self.Qtable[self.position,
self.activity]
                self.next_max = np.max(self.Qtable[self.next_position])

                self.new_value = (1 - self.alpha) * self.old_value +
self.alpha * (self.Q_reward + self.gamma * self.next_max)
```

```
                self.Qtable[self.position, self.activity] =
self.new_value
                self.total_reward+=self.Q_reward

                self.position = self.next_position
            self.Q_reward_array.append(self.total_reward)
        return self.Q_reward_array
```

Explanation:-

1) Setting the position as reset
2) Setting the next step for the action and getting next position, reward, completed and info value.
3) Applying the equation and setting the value to the Qtable
4) Adding the array of the rewards

Code:-

```
def Qtesting(self):

        pygame.init()


        screen = pygame.display.set_mode((250, 250))
        pygame.display.set_caption("Taxi system")
        white = (255, 255, 255)



        self.position = self.env.reset()[0]
        self.Q_reward =  0
        self.completed = False
        self.rewards=0
        time.sleep(0.6)
        running = True
        try:
            while running:
                for event in pygame.event.get():
                    if event.type == pygame.QUIT:
                        running = False
                        pygame.quit()
                        sys.exit()
                    elif event.type == pygame.MOUSEBUTTONDOWN:
                        running = False
                        pygame.quit()
```

```
                        sys.exit()
                    elif self.completed:
                        running = False
                        pygame.quit()
                        sys.exit()
                while not self.completed:
                    self.activity =
np.argmax(self.Qtable[self.position])
                    self.position, self.Q_reward, self.completed,_,_ =
self.env.step(self.activity)

                    self.rewards+=self.Q_reward
                    self.robotaxiImage= (self.env.render())
                    self.surfarray =
pygame.surfarray.make_surface(self.robotaxiImage.swapaxes(0, 1))
                    surfarray = pygame.transform.scale(self.surfarray,
(250, 250))

                    screen.blit(surfarray, (0, 0))

                    pygame.display.flip()
        except SystemExit:
            print("The program has ended")

        return self.rewards
```

Explanation:-

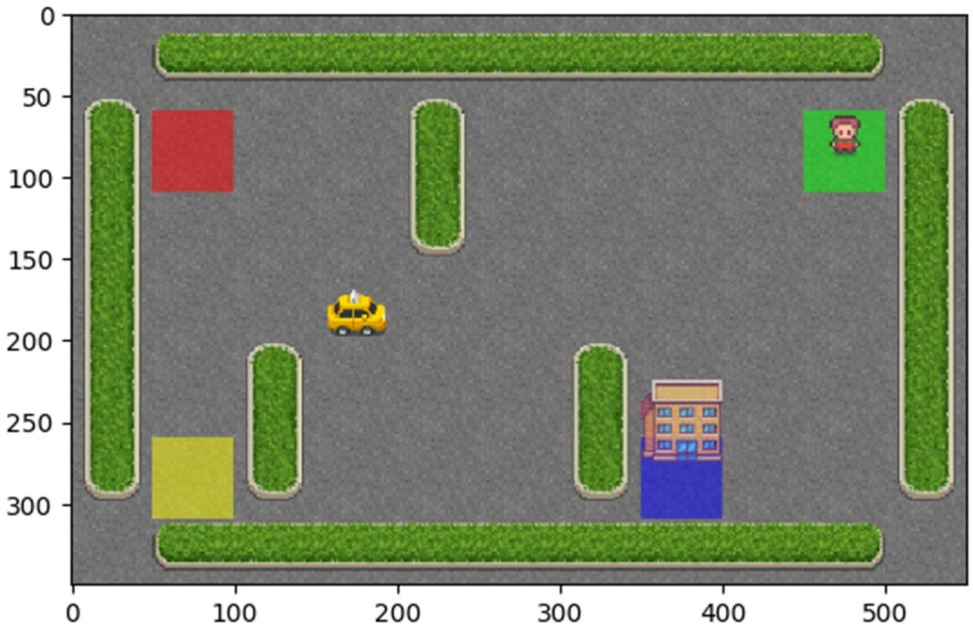
1) Testing the data after the 5000 iteration and getting the next action using the argmax array of the Q learning.
2) Selecting the best the rewards out of it.

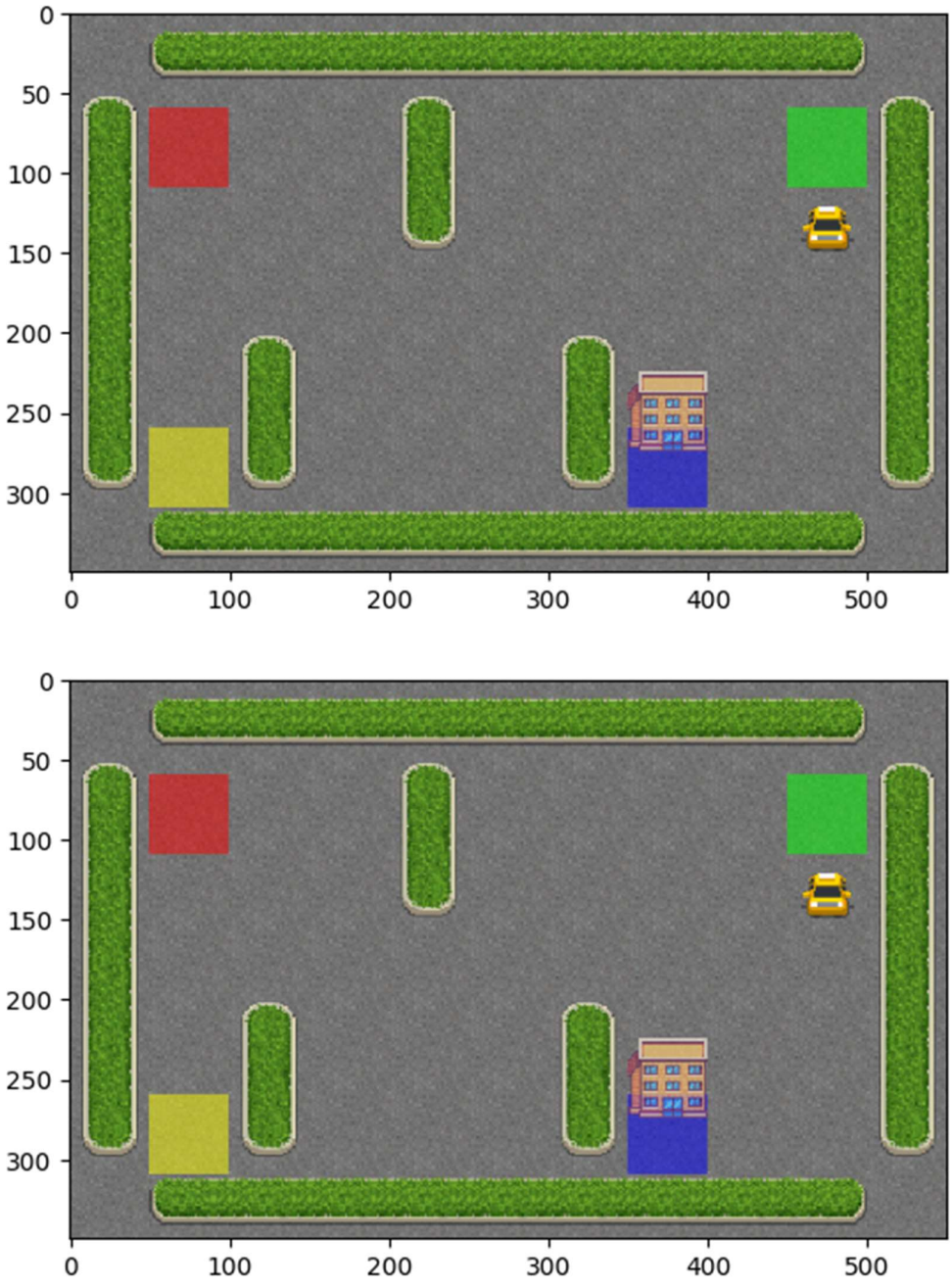
```
    def q_testing_without_image(self, position):
        self.env.reset()
        self.Q_reward =  0
        self.completed = False
        self.rewards=0
        self.position=position
        while not self.completed:
                self.activity = np.argmax(self.Qtable[self.position])
                self.position, self.Q_reward, self.completed,_,_ =
self.env.step(self.activity)

                self.rewards+=self.Q_reward
        return self.rewards
```

```
q_algorithm =QAlgorithm()

Q_learning_start_time = time.time()
Q_learning_training_rewards=q_algorithm.Qtraining()
Q_learning_end_time = time.time()

Q_learning_elapsed_time = Q_learning_end_time - Q_learning_start_time
Q_algorithm_rewards=q_algorithm.Qtesting()
print("Q learning rewards of the test data  "+str(Q_algorithm_rewards))
```

This algorithm is using to run the above functions and printing the rewards from it.

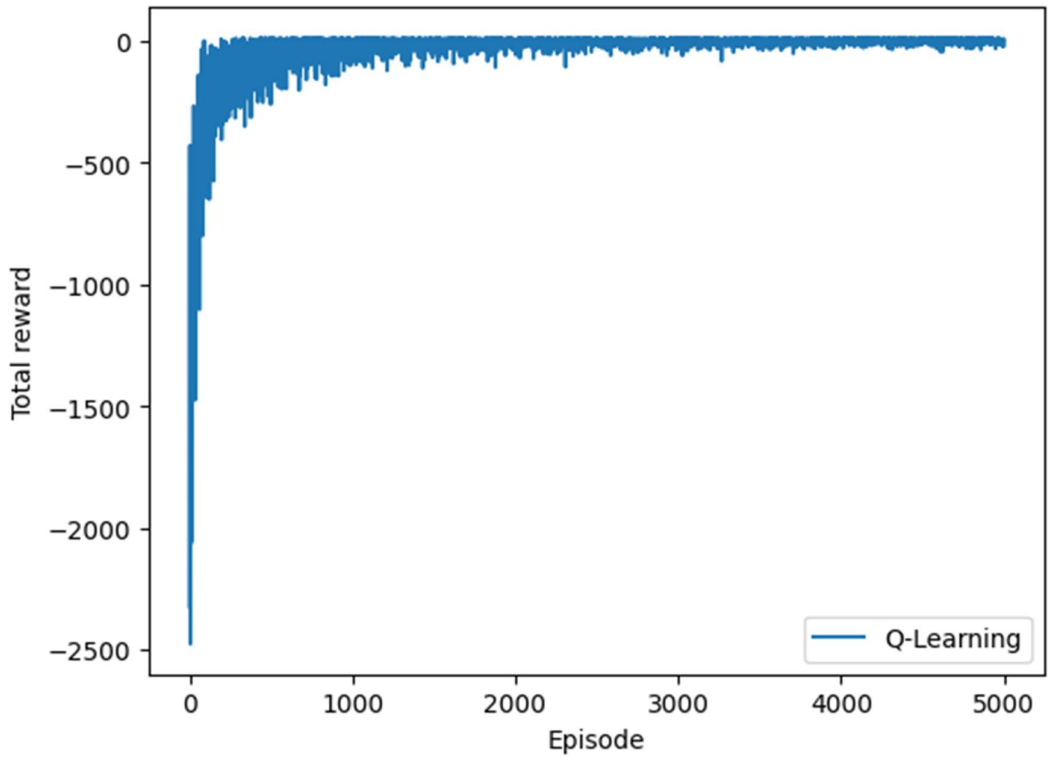
Output:-






```
Q learning rewards of the test data  8

We received an award of 8
```

```
plt.plot(Q_learning_training_rewards, label="Q-Learning")
plt.xlabel("Episode")
plt.ylabel("Total reward")
plt.legend()
plt.show()
```



SARSA Algorithm:-

It is also known as the State Action Reward State Action is based on the Markov Decision process policy[2]. It is also known as on policy learning algorithm.

Code:

```
import random
import numpy as np
from matplotlib import pyplot as plt
from IPython.display import clear_output
import pygame
import sys
import gymnasium as gym
import time
```

Explanation:

Import the algorithm and gymnasium, sys, matplotlib, time, sys, numpy

Code:

```
class SARSA_Algorithm:
    def __init__(self):
        self.env = gym.make("Taxi-v3",render_mode="rgb_array")
        self.SARSA_table = np.zeros((self.env.observation_space.n,
self.env.action_space.n))
        self.alpha=0.5
        self.gamma=0.95
        self.epsilon=0.1
```

Explanation:-

Initializing the basic the like alpha=0.5, gamma=0.95, epsilon=0.1

```
    def SARSA_choose_activity(self, position):
        if random.uniform(0, 1) < self.epsilon:
            activity = self.env.action_space.sample()
        else:
            activity = np.argmax(self.SARSA_table[position, :])
        return activity

    def SARSA_learn(self, position, activity, SARSA_reward,
next_position, next_activity):

        self.SARSA_table[position, activity] =
self.SARSA_table[position, activity] + self.alpha * (SARSA_reward +
self.gamma * self.SARSA_table[next_position, next_activity] -
self.SARSA_table[position, activity])

    def SARSA_run(self, num_episodes=1000):
        SARSA_rewards = []
        SARSA_best_episode_reward = -1000
        best_episode = 0
        for episode in range(num_episodes):
            position = self.env.reset()[0]
            completed = False
            SARSA_total_reward = 0

            activity = self.SARSA_choose_activity(position)
            while not completed:
                next_position, SARSA_reward, completed,_, info =
self.env.step(activity)
                next_activity =
self.SARSA_choose_activity(next_position)
                self.SARSA_learn(position, activity, SARSA_reward,
next_position, next_activity)
```

```
                position = next_position

                activity = next_activity
                SARSA_total_reward += SARSA_reward
            SARSA_rewards.append(SARSA_total_reward)

        return SARSA_rewards
```

Explanation:

1) Choosing the activity based on the table.
2) Learn function works on the based on the multiplication and with alpha and addition of gamma and multiplication of the rewards.
3) Running this algorithm and working on the next activity and next position and adding rewards.

Code:

```
    def SARSA_testrun(self):
        SARSA_final_reward=0
        position=self.env.reset()[0]
        activity = self.SARSA_choose_activity(position)
        pygame.init()
        screen = pygame.display.set_mode((250, 250))
        pygame.display.set_caption("Taxi System using SARSA Algorithm")
        env = gym.make("Taxi-v3",render_mode="rgb_array").env

        white = (255, 255, 255)
        completed=False
        time.sleep(0.6)
        running = True
        try:
            while running:
                for event in pygame.event.get():
                    if event.type == pygame.QUIT:
                        running = False
                        pygame.quit()
                        sys.exit()
                    elif event.type == pygame.MOUSEBUTTONDOWN:
                        running = False
                        pygame.quit()
                        sys.exit()
                    elif completed:
                        running = False
                        pygame.quit()
                        sys.exit()
                while not completed:
```

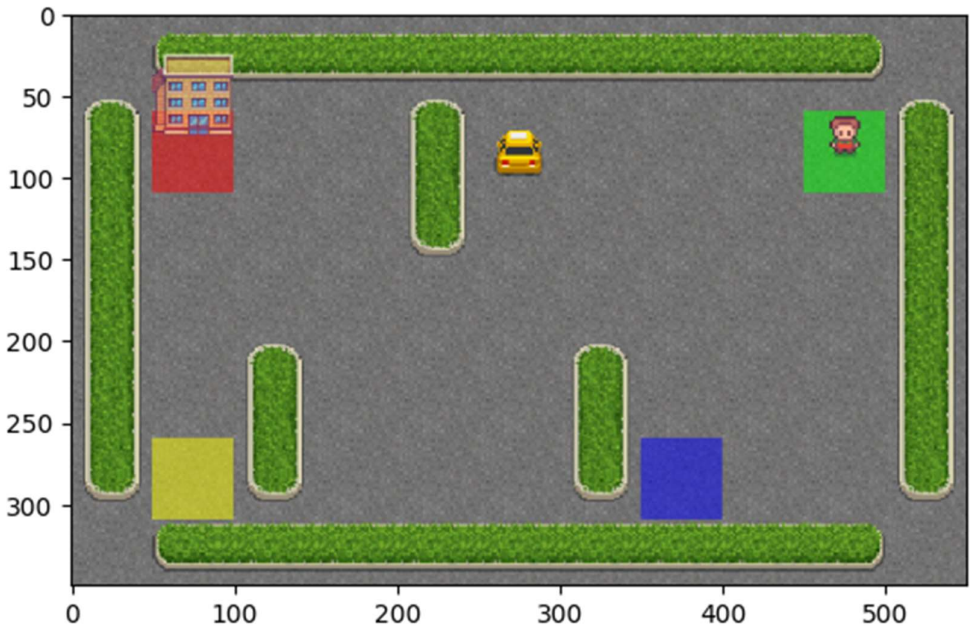
```
                    next_position, SARSA_reward, completed,_,_ =
self.env.step(activity)
                    next_activity =
self.SARSA_choose_activity(next_position)
                    SARSA_final_reward+=SARSA_reward
                    position=next_position
                    activity=next_activity
                    robotaxiImage=self.env.render()
                    surfarray =
pygame.surfarray.make_surface(robotaxiImage.swapaxes(0, 1))
                    surfarray = pygame.transform.scale(surfarray, (250,
250))

                    screen.blit(surfarray, (0, 0))

                    pygame.display.flip()

        except SystemExit:
            print("The program has ended")

        return SARSA_final_reward

        def SARSA_testrun_without_image(self,position):
            self.env.reset()
            SARSA_final_reward=0
            activity = self.SARSA_choose_activity(position)
            completed=False
            while not completed:
                next_position, SARSA_reward, completed,_,_ =
self.env.step(activity)
                next_activity =
self.SARSA_choose_activity(next_position)
                SARSA_final_reward+=SARSA_reward
                position=next_position
                activity=next_activity
        return SARSA_final_reward

def SARSA_plot_rewards(SARSA_rewards):
    plt.plot(SARSA_rewards)
    plt.xlabel("Episode")
    plt.ylabel("Total reward")
    plt.show()

num_episodes = 5000

Sarsa_start_time = time.time()
sarsa_algorithm = SARSA_Algorithm()
sarsa_rewards = sarsa_algorithm.SARSA_run(num_episodes)
```

```
Sarsa_end_time = time.time()

Sarsa_elapsed_time = Sarsa_end_time - Sarsa_start_time
SARSA_final_reward=sarsa_algorithm.SARSA_testrun()
print("For the SARSA test run after the training we recieved the
accuracy of ",SARSA_final_reward)
```

Explanation:-

This is the testing the algorithm and test the time and using the working on it.

Output;-



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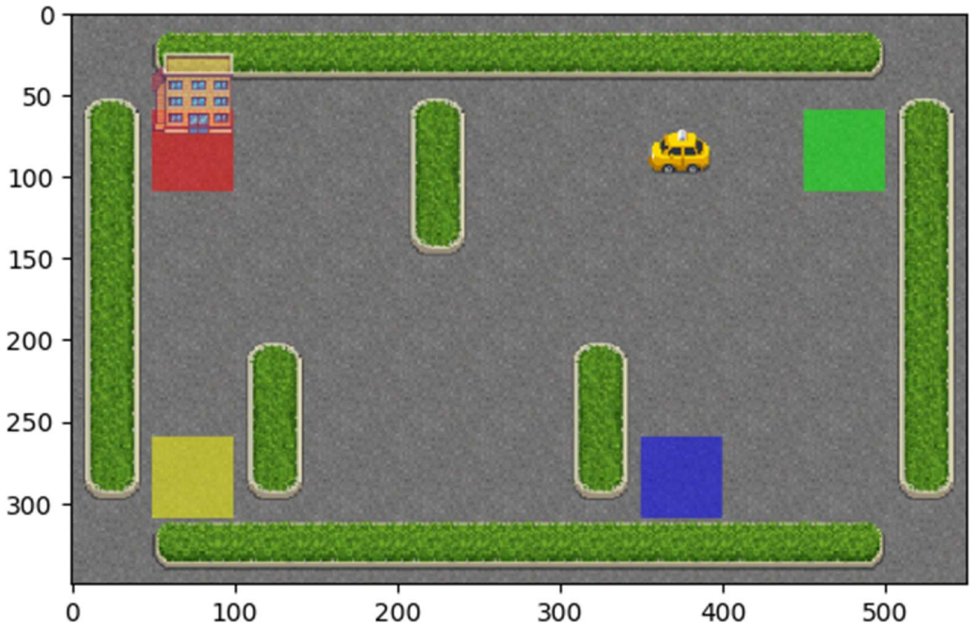
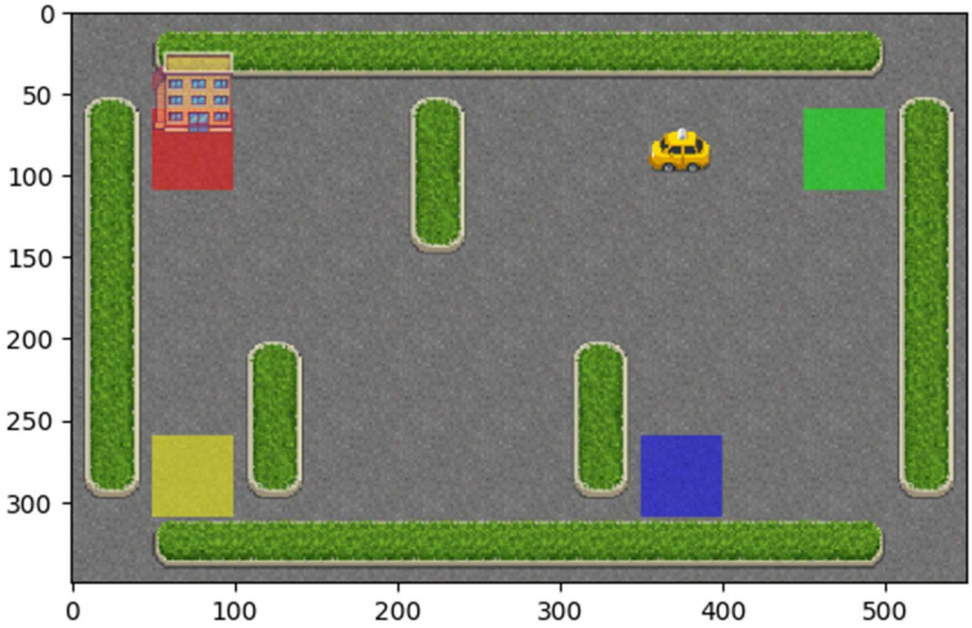
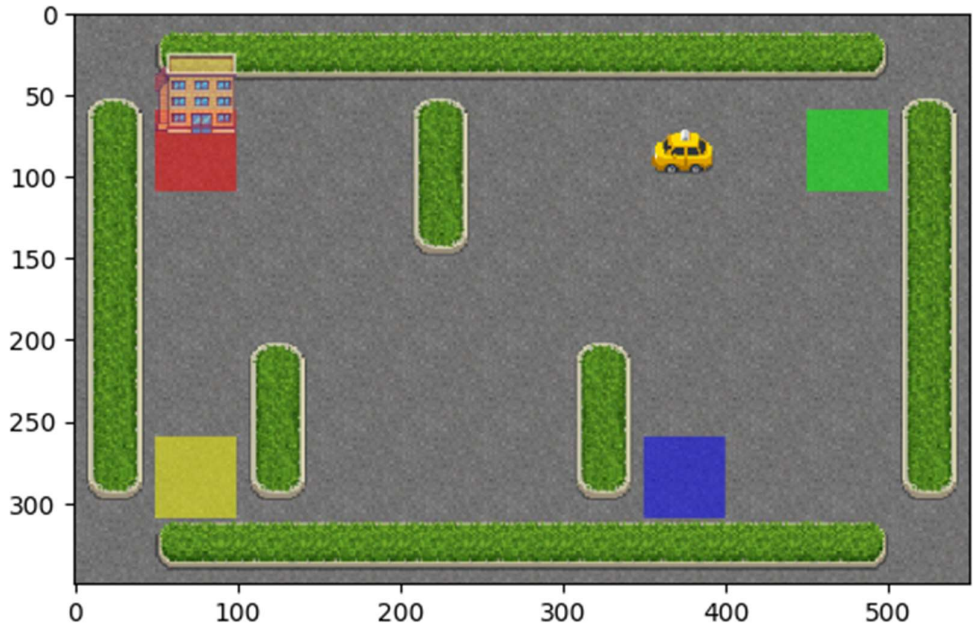
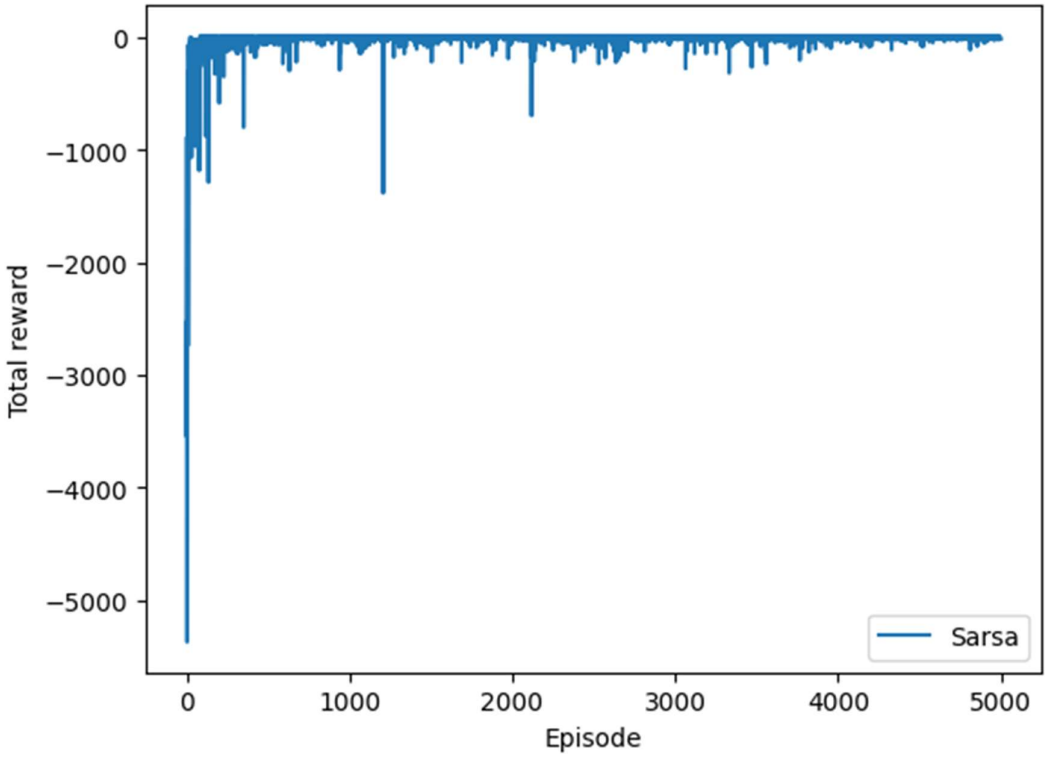






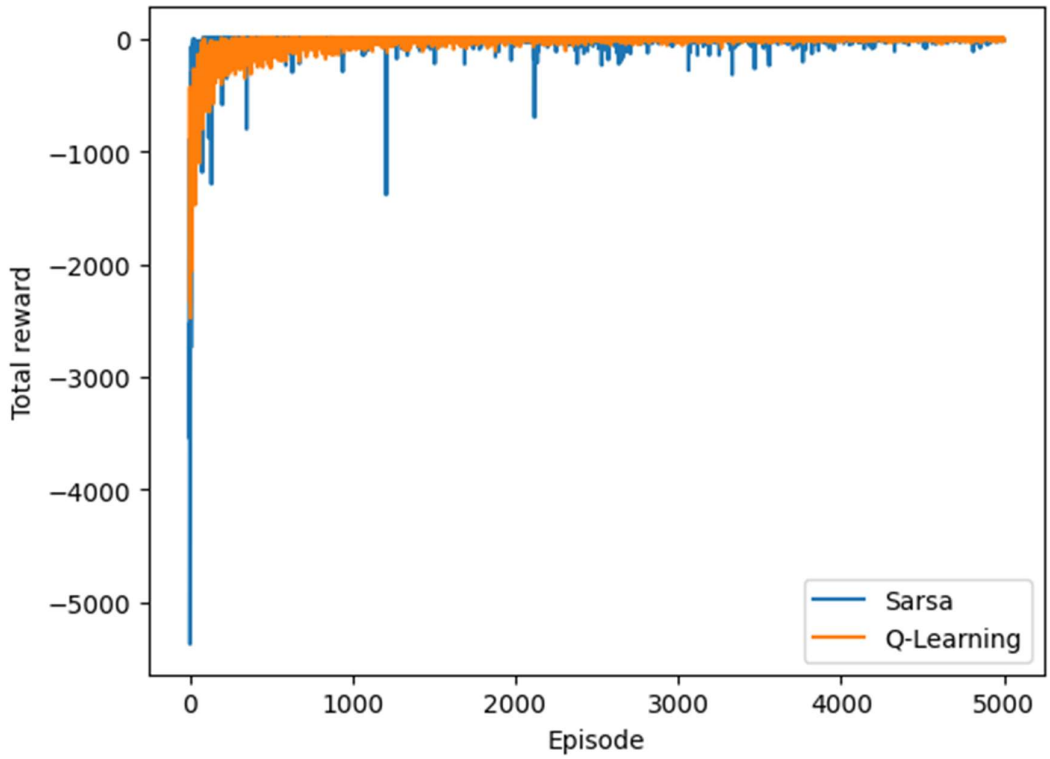

```
The program has ended
For the SARSA test run after the training we recieved the accuracy of
8
```



Evaluation of the code:

```
plt.plot(sarsa_rewards, label="Sarsa")
plt.plot(Q_learning_training_rewards, label="Q-Learning")
```

```
plt.xlabel("Episode")
plt.ylabel("Total reward")
plt.legend()
plt.show()
```




```
print("Time taken to train the Q Learning
Algorithm  "+str(Q_learning_elapsed_time))
print("Time taken to train The SARSA
Algorithm  "+str(Sarsa_elapsed_time))
```

From the Comparison of the we can see that Q learning algorithm is much better than the SARSA algorithm and because it gives much more rewards and performs better consistently. While sometimes the SARSA algorithm fails and does not work even after undergoing the dame training rate and proper tuning.

```
Time taken to train the Q Learning Algorithm  6.920063734054565
Time taken to train The SARSA Algorithm  3.286423683166504
```

But the Q Learning Algorithm takes much more time for the training and sometimes it take the twice the time and the SARSA algorithm.

Reference:-

1) https://www.techtarget.com/searchenterpriseai/definition/Q-learning
2) https://en.wikipedia.org/wiki/State%E2%80%93action%E2%80%93reward%E2%80%93state%E2%80%93action
3) https://builtin.com/machine-learning/sarsa