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**ML Lab Assignment 5**

## **Mountain Climbing**

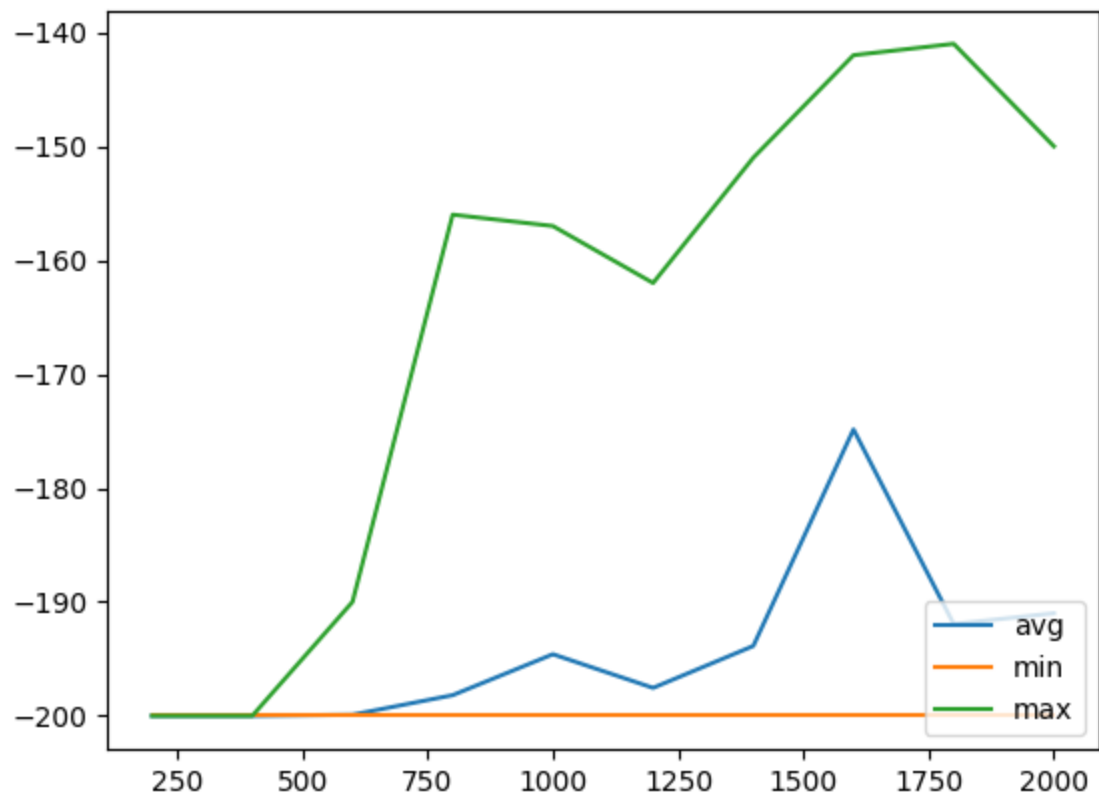
### **Output:-**

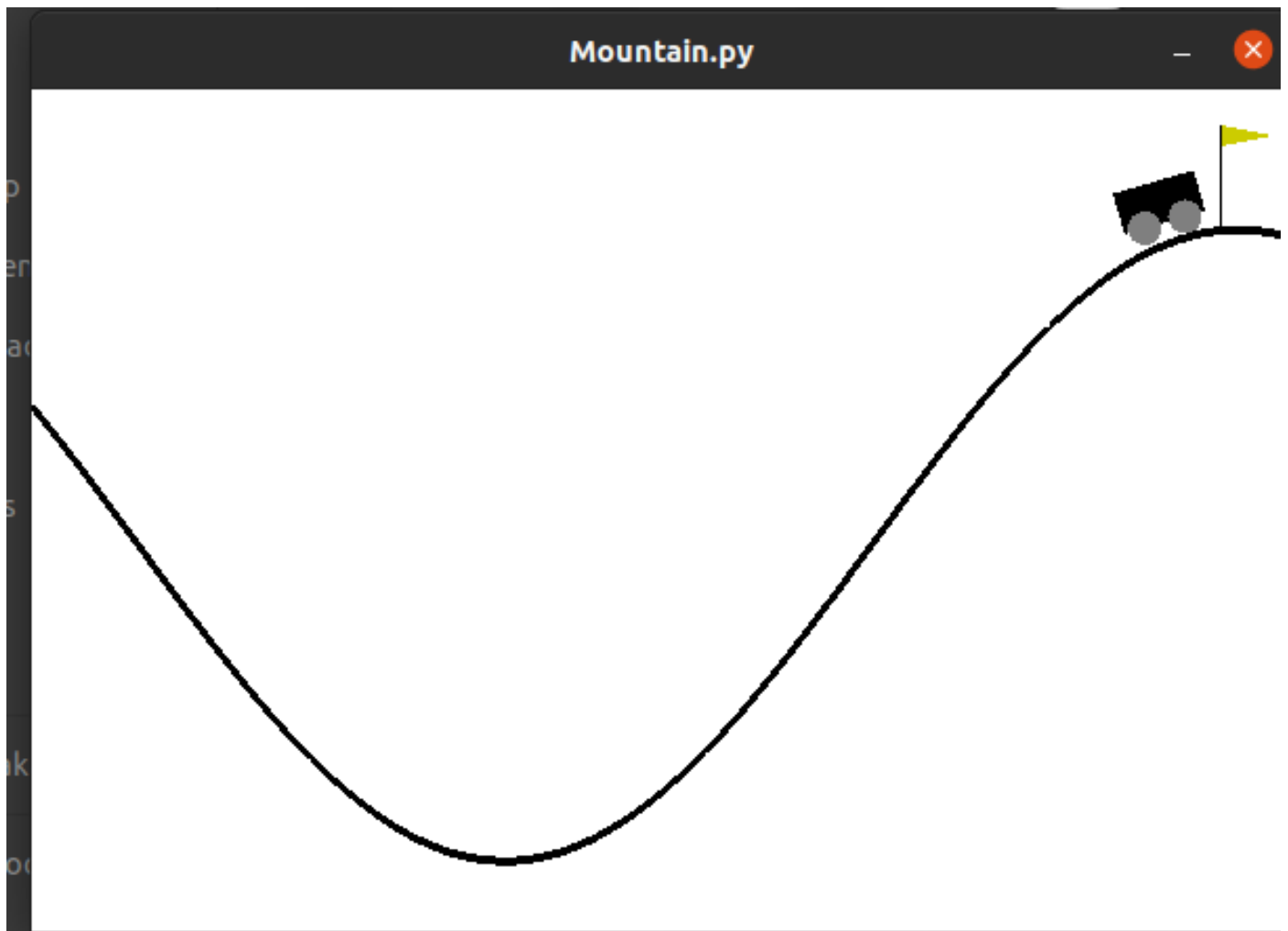
\$ py Mountain.py

Mountain.py:32: DeprecationWarning: `np.int` is a deprecated alias for the builtin `int`. To silence this warning, use `int` by itself. Doing this will not modify any behavior and is safe. When replacing `np.int`, you may wish to use e.g. `np.int64` or `np.int32` to specify the precision. If you wish to review your current use, check the release note link for additional information.

Deprecated in NumPy 1.20; for more details and guidance: <https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations>

```
    return tuple(discrete_state.astype(np.int))
episode: 200, avg: -200.0, min: -200.0, max: -200.0
episode: 400, avg: -200.0, min: -200.0, max: -200.0
episode: 600, avg: -199.905, min: -200.0, max: -190.0
episode: 800, avg: -198.19, min: -200.0, max: -156.0
episode: 1000, avg: -194.595, min: -200.0, max: -157.0
episode: 1200, avg: -197.55, min: -200.0, max: -162.0
episode: 1400, avg: -193.87, min: -200.0, max: -151.0
episode: 1600, avg: -174.86, min: -200.0, max: -142.0
episode: 1800, avg: -191.94, min: -200.0, max: -141.0
episode: 2000, avg: -191.0, min: -200.0, max: -150.0
best reward: -141.0
best episode: 1756
```





Code:-

```
import gym
import matplotlib.pyplot as plt
import numpy as np

env = gym.make("MountainCar-v0")
env.reset()

LEARNING_RATE = 0.1
DISCOUNT = 0.95
EPISODES = 2000

SHOW_EVERY = 200
RENDER_EVERY = 100

DISCRETE_OS_SIZE = [20] * len(env.observation_space.high)
```

```

discrete_os_win_size = (env.observation_space.high - env.observation_space.low) /
DISCRETE_OS_SIZE

epsilon = 0.2
START_EPSILON_DECAYING = 1
END_EPSILON_DECAYING = EPISODES // 2

epsilon_decay_value = epsilon/(END_EPSILON_DECAYING - START_EPSILON_DECAYING)

q_table = np.random.uniform(low=-2, high=0, size=(DISCRETE_OS_SIZE + [env.action_space.n]))

ep_rewards = []
aggr_ep_rewards = {'ep': [], 'avg': [], 'min': [], 'max': []}

def get_discrete_state(state):
    discrete_state = (state - env.observation_space.low) / discrete_os_win_size
    return tuple(discrete_state.astype(np.int))

best_episode_reward = -200
best_episode = -1
best_q_table = q_table
for episode in range(1, EPISODES + 1):
    episode_success = False
    episode_reward = 0
    if not episode % SHOW_EVERY:
        try:
            average_reward = sum(ep_rewards[-SHOW_EVERY:])/len(ep_rewards[-SHOW_EVERY:])
            aggr_ep_rewards['ep'].append(episode)
            aggr_ep_rewards['avg'].append(average_reward)
            aggr_ep_rewards['min'].append(min(ep_rewards[-SHOW_EVERY:]))
            aggr_ep_rewards['max'].append(max(ep_rewards[-SHOW_EVERY:]))
            print(f"episode: {aggr_ep_rewards['ep'][-1]}, avg: {aggr_ep_rewards['avg'][-1]}, "
                  + f"min: {aggr_ep_rewards['min'][-1]}, max: {aggr_ep_rewards['max'][-1]}")
        except Exception as e:
            print(e)

    discrete_state = get_discrete_state(env.reset())
    done = False
    while not done:
        if np.random.random() > epsilon:
            action = np.argmax(q_table[discrete_state])

```

```

else:
    action = np.random.randint(0, env.action_space.n)

    new_state, reward, done, _ = env.step(action)
    episode_reward += reward
    new_discrete_state = get_discrete_state(new_state)
    if RENDER_EVERY > 1:
        if not episode % RENDER_EVERY:
            env.render()
    if not done:
        max_future_q = np.max(q_table[new_discrete_state])
        current_q = q_table[discrete_state + (action, )]
        new_q = (1 - LEARNING_RATE) * current_q + LEARNING_RATE * (reward + DISCOUNT *
max_future_q)
        q_table[discrete_state + (action, )] = new_q
    elif new_state[0] >= env.goal_position:
        episode_success = True
        q_table[discrete_state + (action, )] = 0

    discrete_state = new_discrete_state

if END_EPSILON_DECAYING >= episode >= START_EPSILON_DECAYING:
    epsilon -= epsilon_decay_value

if episode_reward >= best_episode_reward:
    best_episode_reward = episode_reward
    best_episode = episode
    best_q_table = q_table
ep_rewards.append(episode_reward)
env.close()

print(f"best reward: {best_episode_reward}")
print(f"best episode: {best_episode}")

plt.plot(aggr_ep_rewards['ep'], aggr_ep_rewards['avg'], label="avg")
plt.plot(aggr_ep_rewards['ep'], aggr_ep_rewards['min'], label="min")
plt.plot(aggr_ep_rewards['ep'], aggr_ep_rewards['max'], label="max")
plt.legend(loc=4)
plt.show()

```

# **Roulette**

## **Output:-**

\$ py Roulette.py

Number of actions available: 38

Number of states defined: 1

Therefore, Q-Table with 38 columns and 1 rows will be created

Q-Table shape: (1, 38)

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Episode: 2280

Round: 1

Action: 33

Reward: 1.0

Total reward so far: 1.0

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Episode: 2280

Round: 2

Action: 33

Reward: 1.0

Total reward so far: 2.0

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Episode: 2280

Round: 3

Action: 33

Reward: 1.0

Total reward so far: 3.0

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Episode: 2280

Round: 4

Action: 33

Reward: 1.0

Total reward so far: 4.0

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Episode: 2280

Round: 5

Action: 33

Reward: 1.0

Total reward so far: 5.0

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Episode: 2280

Round: 6

Action: 33

Reward: -1.0

Total reward so far: 4.0

\*\*\*\*\*

Episode: 2280

Round: 7

Action: 33

Reward: -1.0

Total reward so far: 3.0

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Episode: 2280

Round: 8

Action: 33

Reward: 1.0

Total reward so far: 4.0

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Episode: 2280

Round: 9

Action: 33

Reward: 1.0

Total reward so far: 5.0

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Episode: 2280

Round: 10

Action: 33

Reward: 1.0

Total reward so far: 6.0

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Episode: 2280

Round: 11

Action: 33

Reward: -1.0

Total reward so far: 5.0

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Episode: 2280  
Round: 12  
Action: 33  
Reward: -1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 13  
Action: 16  
Reward: 1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 14  
Action: 33  
Reward: -1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 15  
Action: 33  
Reward: -1.0  
Total reward so far: 3.0

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Episode: 2280  
Round: 16  
Action: 33  
Reward: -1.0  
Total reward so far: 2.0

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Episode: 2280  
Round: 17  
Action: 16  
Reward: 1.0  
Total reward so far: 3.0

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Episode: 2280



Round: 18  
Action: 16  
Reward: 1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 19  
Action: 16  
Reward: -1.0  
Total reward so far: 3.0

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Episode: 2280  
Round: 20  
Action: 16  
Reward: -1.0  
Total reward so far: 2.0

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Episode: 2280  
Round: 21  
Action: 16  
Reward: 1.0  
Total reward so far: 3.0

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Episode: 2280  
Round: 22  
Action: 16  
Reward: 1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 23  
Action: 16  
Reward: 1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 24  
Action: 16

Reward: 1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 25  
Action: 16  
Reward: -1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 26  
Action: 16  
Reward: 1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 27  
Action: 16  
Reward: -1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 28  
Action: 16  
Reward: 1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 29  
Action: 16  
Reward: 1.0  
Total reward so far: 7.0

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Episode: 2280  
Round: 30  
Action: 16  
Reward: 1.0  
Total reward so far: 8.0

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Episode: 2280  
Round: 31  
Action: 16  
Reward: -1.0  
Total reward so far: 7.0

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Episode: 2280  
Round: 32  
Action: 16  
Reward: -1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 33  
Action: 16  
Reward: 1.0  
Total reward so far: 7.0

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Episode: 2280  
Round: 34  
Action: 16  
Reward: -1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 35  
Action: 16  
Reward: 1.0  
Total reward so far: 7.0

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Episode: 2280  
Round: 36  
Action: 16  
Reward: 1.0  
Total reward so far: 8.0

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Episode: 2280  
Round: 37  
Action: 16  
Reward: -1.0  
Total reward so far: 7.0

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Episode: 2280  
Round: 38  
Action: 16  
Reward: -1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 39  
Action: 16  
Reward: -1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 40  
Action: 16  
Reward: 1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 41  
Action: 16  
Reward: -1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 42  
Action: 16  
Reward: 1.0  
Total reward so far: 6.0

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Episode: 2280  
Round: 43

Action: 16  
Reward: -1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 44  
Action: 16  
Reward: -1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 45  
Action: 16  
Reward: 1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 46  
Action: 16  
Reward: -1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 47  
Action: 16  
Reward: 1.0  
Total reward so far: 5.0

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Episode: 2280  
Round: 48  
Action: 31  
Reward: -1.0  
Total reward so far: 4.0

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Episode: 2280  
Round: 49  
Action: 25  
Reward: 1.0

Total reward so far: 5.0

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Episode: 2280

Round: 50

Action: 16

Reward: 1.0

Total reward so far: 6.0

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Episode: 2280

Round: 51

Action: 16

Reward: 1.0

Total reward so far: 7.0

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Episode: 2280

Round: 52

Action: 16

Reward: 1.0

Total reward so far: 8.0

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Episode: 2280

Round: 53

Action: 16

Reward: -1.0

Total reward so far: 7.0

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Episode: 2280

Round: 54

Action: 0

Reward: 36.0

Total reward so far: 43.0

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Episode: 2280

Round: 55

Action: 0

Reward: -1.0

Total reward so far: 42.0

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Episode: 2280  
Round: 56  
Action: 20  
Reward: -1.0  
Total reward so far: 41.0

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Episode: 2280  
Round: 57  
Action: 0  
Reward: -1.0  
Total reward so far: 40.0

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Episode: 2280  
Round: 58  
Action: 0  
Reward: -1.0  
Total reward so far: 39.0

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Episode: 2280  
Round: 59  
Action: 0  
Reward: -1.0  
Total reward so far: 38.0

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Episode: 2280  
Round: 60  
Action: 0  
Reward: -1.0  
Total reward so far: 37.0

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Episode: 2280  
Round: 61  
Action: 0  
Reward: -1.0  
Total reward so far: 36.0

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Episode: 2280

Round: 62  
Action: 0  
Reward: -1.0  
Total reward so far: 35.0

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Episode: 2280  
Round: 63  
Action: 0  
Reward: -1.0  
Total reward so far: 34.0

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Episode: 2280  
Round: 64  
Action: 0  
Reward: -1.0  
Total reward so far: 33.0

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Episode: 2280  
Round: 65  
Action: 0  
Reward: -1.0  
Total reward so far: 32.0

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Episode: 2280  
Round: 66  
Action: 0  
Reward: -1.0  
Total reward so far: 31.0

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Episode: 2280  
Round: 67  
Action: 0  
Reward: -1.0  
Total reward so far: 30.0

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Episode: 2280  
Round: 68  
Action: 0



Reward: -1.0  
Total reward so far: 29.0

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Episode: 2280  
Round: 69  
Action: 0  
Reward: -1.0  
Total reward so far: 28.0

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Episode: 2280  
Round: 70  
Action: 0  
Reward: -1.0  
Total reward so far: 27.0

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Episode: 2280  
Round: 71  
Action: 0  
Reward: -1.0  
Total reward so far: 26.0

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Episode: 2280  
Round: 72  
Action: 0  
Reward: -1.0  
Total reward so far: 25.0

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Episode: 2280  
Round: 73  
Action: 0  
Reward: 36.0  
Total reward so far: 61.0

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Episode: 2280  
Round: 74  
Action: 0  
Reward: -1.0  
Total reward so far: 60.0

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Episode: 2280  
Round: 75  
Action: 0  
Reward: -1.0  
Total reward so far: 59.0

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Episode: 2280  
Round: 76  
Action: 0  
Reward: -1.0  
Total reward so far: 58.0

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Episode: 2280  
Round: 77  
Action: 0  
Reward: -1.0  
Total reward so far: 57.0

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Episode: 2280  
Round: 78  
Action: 0  
Reward: -1.0  
Total reward so far: 56.0

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Episode: 2280  
Round: 79  
Action: 0  
Reward: 36.0  
Total reward so far: 92.0

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Episode: 2280  
Round: 80  
Action: 0  
Reward: -1.0  
Total reward so far: 91.0

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Episode: 2280  
Round: 81  
Action: 0  
Reward: -1.0  
Total reward so far: 90.0

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Episode: 2280  
Round: 82  
Action: 0  
Reward: -1.0  
Total reward so far: 89.0

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Episode: 2280  
Round: 83  
Action: 0  
Reward: -1.0  
Total reward so far: 88.0

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Episode: 2280  
Round: 84  
Action: 0  
Reward: -1.0  
Total reward so far: 87.0

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Episode: 2280  
Round: 85  
Action: 0  
Reward: -1.0  
Total reward so far: 86.0

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Episode: 2280  
Round: 86  
Action: 0  
Reward: -1.0  
Total reward so far: 85.0

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Episode: 2280  
Round: 87

Action: 0  
Reward: -1.0  
Total reward so far: 84.0

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Episode: 2280  
Round: 88  
Action: 5  
Reward: 1.0  
Total reward so far: 85.0

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Episode: 2280  
Round: 89  
Action: 0  
Reward: -1.0  
Total reward so far: 84.0

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Episode: 2280  
Round: 90  
Action: 0  
Reward: -1.0  
Total reward so far: 83.0

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Episode: 2280  
Round: 91  
Action: 0  
Reward: -1.0  
Total reward so far: 82.0

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Episode: 2280  
Round: 92  
Action: 0  
Reward: -1.0  
Total reward so far: 81.0

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Episode: 2280  
Round: 93  
Action: 0  
Reward: -1.0

Total reward so far: 80.0

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Episode: 2280

Round: 94

Action: 0

Reward: -1.0

Total reward so far: 79.0

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Episode: 2280

Round: 95

Action: 0

Reward: -1.0

Total reward so far: 78.0

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Episode: 2280

Round: 96

Action: 0

Reward: -1.0

Total reward so far: 77.0

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Episode: 2280

Round: 97

Action: 25

Reward: -1.0

Total reward so far: 76.0

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Episode: 2280

Round: 98

Action: 0

Reward: 36.0

Total reward so far: 112.0

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Episode: 2280

Round: 99

Action: 0

Reward: -1.0

Total reward so far: 111.0

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Episode: 2280

Round: 100

Action: 0

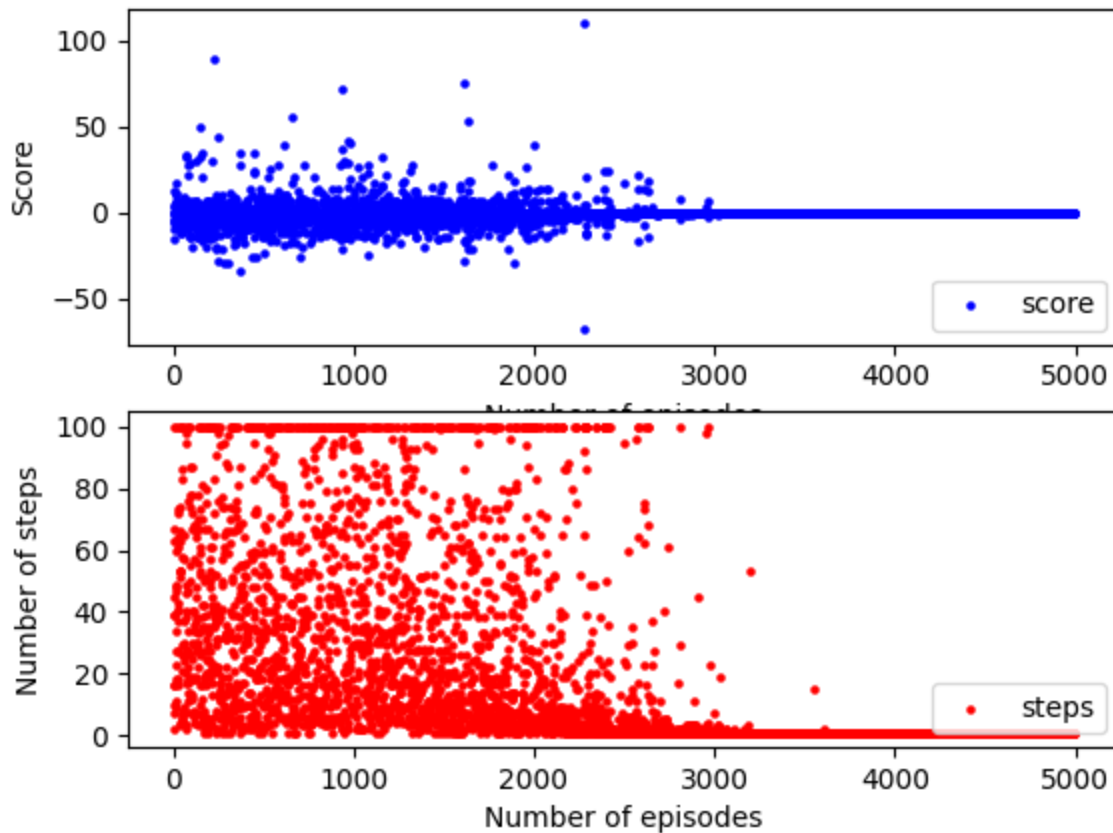
Reward: -1.0

Total reward so far: 110.0

Q-Table after 5000 episodes

```
[[ -3.07583358e-02 -4.19334032e-02 -5.99201427e-02 -3.76336086e-02  
  -9.83211895e-02 -1.35208913e-02 -1.48916007e-02 -7.34094117e-02  
  -2.78890312e-02 -2.38599619e-02 -8.43982923e-02 -2.09545907e-02  
  -3.38959585e-02 -7.01535786e-02 -5.08198245e-02 -8.84553123e-03  
  -7.96039430e-02 -7.43652260e-02 -2.86639392e-02 -6.85138461e-02  
  -7.48503926e-02 -3.73022417e-02 -1.20240760e-02 -2.79969394e-02  
  -1.20484291e-02 -6.39220388e-02 -4.02999360e-02 -3.19100504e-03  
  -6.82564864e-02 -7.04195457e-02 -2.58737313e-04 -1.96667366e-02  
  -4.47963458e-02 -4.82113761e-02 -6.84705007e-02 -3.36668727e-02  
  -2.11633852e-02  1.57973762e-06]]
```

The best score after running 5000 episodes: 110.0



Code:-

```
import gym
import gym_toytext
import numpy as np
from IPython.display import clear_output
from time import sleep
import matplotlib.pyplot as plt

env = gym.make('Roulette-v0')

action_space_size = env.action_space.n
state_space_size = env.observation_space.n
print(f"Number of actions available: {action_space_size}")
print(f"Number of states defined: {state_space_size}")
print(f"Therefore, Q-Table with {action_space_size} columns and {state_space_size} rows
will be created")

q_table = np.random.random([state_space_size, action_space_size])
```

```

#OR
# q_table = np.zeros([state_space_size, action_space_size])
print(f"Q-Table shape: {q_table.shape}")

sleep(5)

# Hyperparameters
TOTAL_EPISODES = 5_000 #Number of episodes to train the algorithm
MAX_STEPS = 150 #Max steps an agent can take during an episode

LEARNING_RATE = 0.1
GAMMA = 0.95 # Discount (close to 0 makes it greedy, close to 1 considers long term)

# Exploration Parameters
epsilon = 1
START_EPSILON_DECAYING = 1
END_EPSILON_DECAYING = TOTAL_EPISODES // 2
DECAY_RATE = epsilon/(END_EPSILON_DECAYING - START_EPSILON_DECAYING)

def print_frames(frames):
    total_reward = 0
    for i, frame in enumerate(frames):
        clear_output(wait=True)
        print('\n*****')
        print(f"Episode: {frame['episode']}")
        print(f'Round: {i + 1}')
        print(f"Action: {frame['action']}")
        print(f"Reward: {frame['reward']}")
        total_reward += frame['reward']
        print(f"Total reward so far: {total_reward}")
        sleep(0.1)

def edit_reward(info):
    print(info)

env.reset()
history = {'steps': [], 'total_score': [], 'episode_number': []}
best_frames = []
high_score = 0

for episode in range(TOTAL_EPISODES):

    state = env.reset()
    step = 0

```



```

frames = []
current_score = 0
done = False

for step in range(MAX_STEPS):

    if np.random.random() > epsilon: #This is exploitation
        action = np.argmax(q_table[state, :]) #Current state, max value
    else: #This is exploration
        action = np.random.randint(0, action_space_size)

    new_state, reward, done, info = env.step(action)

    current_score += reward

    frames.append({
        'episode': episode,
        'action': action,
        'reward': reward
    })

    q_table[state, action] = (1 - LEARNING_RATE) * q_table[state, action] +
LEARNING_RATE * (reward + GAMMA * np.max(q_table[new_state, :]))

    if done:

        history['steps'].append(step + 1)
        history['total_score'].append(current_score)
        history['episode_number'].append(episode)

        if current_score >= high_score:
            high_score = current_score
            best_frames = frames.copy()
            break

    state = new_state

    if END_EPSILON_DECAYING >= episode >= START_EPSILON_DECAYING:
        epsilon -= DECAY_RATE

env.close()
print_frames(best_frames)
print(f"\nQ-Table after {TOTAL_EPISODES} episodes")
print(q_table)
print(f'The best score after running {TOTAL_EPISODES} episodes: {high_score}')

```

```
# Total score
plt.subplot(2, 1, 1)
plt.scatter(history['episode_number'], history['total_score'], s = 5, label = 'score',
            color = 'blue')
plt.xlabel('Number of episodes')
plt.ylabel('Score')
plt.legend(loc = 4)

# Number of steps
plt.subplot(2, 1, 2)
plt.scatter(history['episode_number'], history['steps'], s = 5, label = 'steps', color =
            'red')
plt.xlabel('Number of episodes')
plt.ylabel('Number of steps')
plt.legend(loc = 4)
plt.show()
```