

# mab-click-through-rate

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**0.0.1 Group ID: DRL GROUP 73**

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## 1 Background

In digital advertising, Click-Through Rate (CTR) is a critical metric that measures the effectiveness of an advertisement. It is calculated as the ratio of users who click on an ad to the number of users who view the ad. A higher CTR indicates more successful engagement with the audience, which can lead to increased conversions and revenue. From time-to-time advertisers experiment with various elements/targeting of an ad to optimise the ROI.

## 2 Scenario

Imagine an innovative digital advertising agency, AdMasters Inc., that specializes in maximizing click-through rates (CTR) for their clients' advertisements. One of their clients has identified four key tunable elements in their ads: *Age*, *City*, *Gender*, and *Mobile Operating System (OS)*. These elements significantly influence user engagement and conversion rates. The client is keen to optimize their CTR while minimizing resource expenditure.

## 3 Objective

Optimize the CTR of digital ads by employing Multi Arm Bandit algorithms. System should dynamically and efficiently allocate ad displays to maximize overall CTR.

## 4 Dataset

The dataset for Ads contains 4 unique features/characteristics. \* Age (Range: 25:50) \* City (Possible Values: 'New York', 'Los Angeles', 'Chicago', 'Houston', 'Phoenix') \* Gender (Possible Values: 'Male', 'Female') \* OS: (Possible Values: 'iOS', 'Android', 'Other')

**Link for accessing dataset:** <https://drive.google.com/file/d/1Y5HmEeoQsafo9Diy9piS69qEMnC0g1ys/view?us>

## 5 Environment Details

**Arms:** Each arm represents a different ad from the dataset.

**Reward Function:** \* Probability of a Male clicking on an Ad -> 0.7 (randomly generated) \* Probability of a Female clicking on an Ad -> 0.6 (randomly generated) \* Once probabilities are assigned to all the values, create a final reward (clicked or not clicked binary outcome) based on the assumed probabilities in step 1 (by combining the probabilities of each feature value present in that ad)

**Assumptions** \* Assume  $\alpha = \beta = 1$  for cold start \* Explore Percentage = 10% \* Run the simulation for min 1000 iterations

## 6 Requirements and Deliverables:

Implement the Multi-Arm Bandit Problem for the given above scenario for all the below mentioned policy methods.

### 6.0.1 Initialize constants

```
[44]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

```
[45]: # Constants
# Constants
epsilon = 0.1
alpha = 1
beta = 1
```

## 7 Load Dataset

```
[46]: df = pd.read_csv('/content/AD_Click.csv')
print(df.head())
```

	Age	Gender	City	Phone_OS
0	25	Male	New York	iOS
1	25	Male	New York	Android
2	25	Male	New York	Other
3	25	Male	Los Angeles	iOS
4	25	Male	Los Angeles	Android

```
[47]: print(df.describe())
print("Dataset loaded successfully. Statistics:")
print(df.info())
```

	Age
count	780.000000

```

mean    37.500000
std      7.504812
min     25.000000
25%     31.000000
50%     37.500000
75%     44.000000
max     50.000000
Dataset loaded successfully. Statistics:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 780 entries, 0 to 779
Data columns (total 4 columns):
#   Column      Non-Null Count  Dtype
---  -
0   Age         780 non-null    int64
1   Gender      780 non-null    object
2   City        780 non-null    object
3   Phone_OS    780 non-null    object
dtypes: int64(1), object(3)
memory usage: 24.5+ KB
None

```

## 8 Design a CTR Environment (1M)

```

[48]: class CTREnvironment:
    def __init__(self, df):
        """
        Initializes the environment with the provided dataframe.

        Parameters:
        - df (pandas.DataFrame): DataFrame containing ad information.
        """
        self.df = df
        self.n_arms = len(df) # Number of arms (ads)
        self.total_reward = 0 # Total reward accumulated
        self.counts = np.zeros(self.n_arms) # Count of selections for each arm
        self.values = np.zeros(self.n_arms) # Estimated value of each arm
        self.click_probs = self._assign_click_probabilities() # Click-through
        ↪ probabilities for each arm

    def _assign_click_probabilities(self):
        """
        Assigns click-through probabilities for each ad based on gender, city,
        ↪ and phone OS.

        Returns:
        - list: List of click-through probabilities for each ad.

```

```

    """
    probs = []
    for idx in range(self.n_arms):
        ad = self.df.iloc[idx]
        gender_prob = 0.7 if ad['Gender'] == 'Male' else 0.6 # Higher
↪click probability for males
        city_prob = np.random.rand() # Random city-based click probability
        phone_os_prob = np.random.rand() # Random phone OS-based click
↪probability
        combined_prob = gender_prob * city_prob * phone_os_prob # Combined
↪probability
        probs.append(combined_prob)
    return probs

def reset(self):
    """
    Resets the environment: clears rewards, counts, and values.
    """
    self.total_reward = 0
    self.counts.fill(0)
    self.values.fill(0)

def select_arm(self, arm):
    """
    Selects an arm (ad) and returns the reward (1 for click, 0 for no
↪click).

    Parameters:
    - arm (int): Index of the arm (ad) to select.

    Returns:
    - int: Reward (1 for click, 0 for no click).
    """
    self.counts[arm] += 1 # Increment count for selected arm
    reward = np.random.rand() < self.click_probs[arm] # Simulate click
↪based on probability
    reward = 1 if reward else 0 # Convert boolean to integer reward
    n = self.counts[arm]
    value = self.values[arm]
    # Update estimated value using incremental formula (weighted average)
    self.values[arm] = ((n - 1) / float(n)) * value + (1 / float(n)) *
↪reward
    self.total_reward += reward # Accumulate total reward
    return reward

```

```
# Initialize environment
env = CTREnvironment(df)
```

## 9 Using Random Policy (0.5M)

Print all the iterations with random policy selected for the given Ad. (Mandatory)

```
[49]: def random_policy(env, iterations):
      """
      Implements a random policy for selecting arms (ads) in the environment.

      Parameters:
      - env (CTREnvironment): The environment object containing ads and their
      ↪ probabilities.
      - iterations (int): Number of iterations (rounds) to run the policy.

      Returns:
      - list: List of total rewards accumulated after each iteration.
      """
      total_rewards = [] # List to store cumulative rewards after each iteration
      rewards = [] # List to store rewards obtained in each iteration

      for i in range(iterations):
          arm = np.random.randint(env.n_arms) # Randomly select an arm (ad)
          reward = env.select_arm(arm) # Get reward for selecting the arm
          rewards.append(reward) # Append reward to the list of rewards
          total_rewards.append(sum(rewards)) # Append cumulative total rewards
          print(f"Iteration {i+1}: Reward = {reward}, Total Rewards =
          ↪ {total_rewards[-1]}") # Print iteration details

      return total_rewards # Return list of total rewards accumulated

env.reset() # Reset the environment
random_rewards = random_policy(env, 1000) # Execute random policy for 1000
↪ iterations
print("Total Rewards from Random Policy:", random_rewards[-1]) # Print total
↪ rewards accumulated
```

```
Iteration 1: Reward = 0, Total Rewards = 0
Iteration 2: Reward = 0, Total Rewards = 0
Iteration 3: Reward = 0, Total Rewards = 0
Iteration 4: Reward = 0, Total Rewards = 0
Iteration 5: Reward = 0, Total Rewards = 0
Iteration 6: Reward = 1, Total Rewards = 1
Iteration 7: Reward = 0, Total Rewards = 1
Iteration 8: Reward = 1, Total Rewards = 2
Iteration 9: Reward = 0, Total Rewards = 2
```

Iteration 10: Reward = 1, Total Rewards = 3  
Iteration 11: Reward = 0, Total Rewards = 3  
Iteration 12: Reward = 0, Total Rewards = 3  
Iteration 13: Reward = 1, Total Rewards = 4  
Iteration 14: Reward = 0, Total Rewards = 4  
Iteration 15: Reward = 1, Total Rewards = 5  
Iteration 16: Reward = 0, Total Rewards = 5  
Iteration 17: Reward = 1, Total Rewards = 6  
Iteration 18: Reward = 0, Total Rewards = 6  
Iteration 19: Reward = 0, Total Rewards = 6  
Iteration 20: Reward = 0, Total Rewards = 6  
Iteration 21: Reward = 0, Total Rewards = 6  
Iteration 22: Reward = 1, Total Rewards = 7  
Iteration 23: Reward = 0, Total Rewards = 7  
Iteration 24: Reward = 0, Total Rewards = 7  
Iteration 25: Reward = 0, Total Rewards = 7  
Iteration 26: Reward = 0, Total Rewards = 7  
Iteration 27: Reward = 0, Total Rewards = 7  
Iteration 28: Reward = 0, Total Rewards = 7  
Iteration 29: Reward = 1, Total Rewards = 8  
Iteration 30: Reward = 0, Total Rewards = 8  
Iteration 31: Reward = 0, Total Rewards = 8  
Iteration 32: Reward = 1, Total Rewards = 9  
Iteration 33: Reward = 1, Total Rewards = 10  
Iteration 34: Reward = 0, Total Rewards = 10  
Iteration 35: Reward = 0, Total Rewards = 10  
Iteration 36: Reward = 0, Total Rewards = 10  
Iteration 37: Reward = 0, Total Rewards = 10  
Iteration 38: Reward = 1, Total Rewards = 11  
Iteration 39: Reward = 0, Total Rewards = 11  
Iteration 40: Reward = 0, Total Rewards = 11  
Iteration 41: Reward = 0, Total Rewards = 11  
Iteration 42: Reward = 0, Total Rewards = 11  
Iteration 43: Reward = 0, Total Rewards = 11  
Iteration 44: Reward = 1, Total Rewards = 12  
Iteration 45: Reward = 0, Total Rewards = 12  
Iteration 46: Reward = 0, Total Rewards = 12  
Iteration 47: Reward = 1, Total Rewards = 13  
Iteration 48: Reward = 0, Total Rewards = 13  
Iteration 49: Reward = 0, Total Rewards = 13  
Iteration 50: Reward = 0, Total Rewards = 13  
Iteration 51: Reward = 0, Total Rewards = 13  
Iteration 52: Reward = 0, Total Rewards = 13  
Iteration 53: Reward = 0, Total Rewards = 13  
Iteration 54: Reward = 0, Total Rewards = 13  
Iteration 55: Reward = 0, Total Rewards = 13  
Iteration 56: Reward = 1, Total Rewards = 14  
Iteration 57: Reward = 0, Total Rewards = 14

Iteration 58: Reward = 0, Total Rewards = 14  
Iteration 59: Reward = 0, Total Rewards = 14  
Iteration 60: Reward = 1, Total Rewards = 15  
Iteration 61: Reward = 0, Total Rewards = 15  
Iteration 62: Reward = 0, Total Rewards = 15  
Iteration 63: Reward = 0, Total Rewards = 15  
Iteration 64: Reward = 0, Total Rewards = 15  
Iteration 65: Reward = 0, Total Rewards = 15  
Iteration 66: Reward = 0, Total Rewards = 15  
Iteration 67: Reward = 0, Total Rewards = 15  
Iteration 68: Reward = 1, Total Rewards = 16  
Iteration 69: Reward = 1, Total Rewards = 17  
Iteration 70: Reward = 0, Total Rewards = 17  
Iteration 71: Reward = 0, Total Rewards = 17  
Iteration 72: Reward = 0, Total Rewards = 17  
Iteration 73: Reward = 0, Total Rewards = 17  
Iteration 74: Reward = 0, Total Rewards = 17  
Iteration 75: Reward = 0, Total Rewards = 17  
Iteration 76: Reward = 0, Total Rewards = 17  
Iteration 77: Reward = 0, Total Rewards = 17  
Iteration 78: Reward = 0, Total Rewards = 17  
Iteration 79: Reward = 0, Total Rewards = 17  
Iteration 80: Reward = 0, Total Rewards = 17  
Iteration 81: Reward = 0, Total Rewards = 17  
Iteration 82: Reward = 1, Total Rewards = 18  
Iteration 83: Reward = 0, Total Rewards = 18  
Iteration 84: Reward = 0, Total Rewards = 18  
Iteration 85: Reward = 0, Total Rewards = 18  
Iteration 86: Reward = 0, Total Rewards = 18  
Iteration 87: Reward = 0, Total Rewards = 18  
Iteration 88: Reward = 1, Total Rewards = 19  
Iteration 89: Reward = 1, Total Rewards = 20  
Iteration 90: Reward = 0, Total Rewards = 20  
Iteration 91: Reward = 1, Total Rewards = 21  
Iteration 92: Reward = 0, Total Rewards = 21  
Iteration 93: Reward = 1, Total Rewards = 22  
Iteration 94: Reward = 0, Total Rewards = 22  
Iteration 95: Reward = 0, Total Rewards = 22  
Iteration 96: Reward = 1, Total Rewards = 23  
Iteration 97: Reward = 0, Total Rewards = 23  
Iteration 98: Reward = 0, Total Rewards = 23  
Iteration 99: Reward = 1, Total Rewards = 24  
Iteration 100: Reward = 0, Total Rewards = 24  
Iteration 101: Reward = 0, Total Rewards = 24  
Iteration 102: Reward = 0, Total Rewards = 24  
Iteration 103: Reward = 0, Total Rewards = 24  
Iteration 104: Reward = 0, Total Rewards = 24  
Iteration 105: Reward = 1, Total Rewards = 25

Iteration 106: Reward = 0, Total Rewards = 25  
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Iteration 109: Reward = 0, Total Rewards = 25  
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Iteration 112: Reward = 0, Total Rewards = 26  
Iteration 113: Reward = 0, Total Rewards = 26  
Iteration 114: Reward = 0, Total Rewards = 26  
Iteration 115: Reward = 0, Total Rewards = 26  
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Iteration 117: Reward = 0, Total Rewards = 26  
Iteration 118: Reward = 0, Total Rewards = 26  
Iteration 119: Reward = 1, Total Rewards = 27  
Iteration 120: Reward = 0, Total Rewards = 27  
Iteration 121: Reward = 0, Total Rewards = 27  
Iteration 122: Reward = 0, Total Rewards = 27  
Iteration 123: Reward = 0, Total Rewards = 27  
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Iteration 132: Reward = 0, Total Rewards = 27  
Iteration 133: Reward = 0, Total Rewards = 27  
Iteration 134: Reward = 1, Total Rewards = 28  
Iteration 135: Reward = 0, Total Rewards = 28  
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Iteration 137: Reward = 0, Total Rewards = 28  
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Iteration 139: Reward = 0, Total Rewards = 28  
Iteration 140: Reward = 1, Total Rewards = 29  
Iteration 141: Reward = 0, Total Rewards = 29  
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Iteration 143: Reward = 0, Total Rewards = 29  
Iteration 144: Reward = 1, Total Rewards = 30  
Iteration 145: Reward = 0, Total Rewards = 30  
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Iteration 153: Reward = 1, Total Rewards = 31



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Iteration 162: Reward = 1, Total Rewards = 32  
Iteration 163: Reward = 0, Total Rewards = 32  
Iteration 164: Reward = 0, Total Rewards = 32  
Iteration 165: Reward = 0, Total Rewards = 32  
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Iteration 219: Reward = 0, Total Rewards = 40  
Iteration 220: Reward = 1, Total Rewards = 41  
Iteration 221: Reward = 0, Total Rewards = 41  
Iteration 222: Reward = 0, Total Rewards = 41  
Iteration 223: Reward = 0, Total Rewards = 41  
Iteration 224: Reward = 0, Total Rewards = 41  
Iteration 225: Reward = 0, Total Rewards = 41  
Iteration 226: Reward = 1, Total Rewards = 42  
Iteration 227: Reward = 0, Total Rewards = 42  
Iteration 228: Reward = 0, Total Rewards = 42  
Iteration 229: Reward = 0, Total Rewards = 42  
Iteration 230: Reward = 0, Total Rewards = 42  
Iteration 231: Reward = 1, Total Rewards = 43  
Iteration 232: Reward = 0, Total Rewards = 43  
Iteration 233: Reward = 0, Total Rewards = 43  
Iteration 234: Reward = 0, Total Rewards = 43  
Iteration 235: Reward = 1, Total Rewards = 44  
Iteration 236: Reward = 0, Total Rewards = 44  
Iteration 237: Reward = 0, Total Rewards = 44  
Iteration 238: Reward = 0, Total Rewards = 44  
Iteration 239: Reward = 0, Total Rewards = 44  
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Iteration 253: Reward = 0, Total Rewards = 44  
Iteration 254: Reward = 0, Total Rewards = 44  
Iteration 255: Reward = 0, Total Rewards = 44  
Iteration 256: Reward = 0, Total Rewards = 44  
Iteration 257: Reward = 0, Total Rewards = 44  
Iteration 258: Reward = 1, Total Rewards = 45  
Iteration 259: Reward = 0, Total Rewards = 45  
Iteration 260: Reward = 0, Total Rewards = 45  
Iteration 261: Reward = 1, Total Rewards = 46  
Iteration 262: Reward = 0, Total Rewards = 46  
Iteration 263: Reward = 0, Total Rewards = 46  
Iteration 264: Reward = 1, Total Rewards = 47  
Iteration 265: Reward = 0, Total Rewards = 47  
Iteration 266: Reward = 0, Total Rewards = 47  
Iteration 267: Reward = 0, Total Rewards = 47  
Iteration 268: Reward = 0, Total Rewards = 47  
Iteration 269: Reward = 1, Total Rewards = 48  
Iteration 270: Reward = 0, Total Rewards = 48  
Iteration 271: Reward = 1, Total Rewards = 49  
Iteration 272: Reward = 0, Total Rewards = 49  
Iteration 273: Reward = 0, Total Rewards = 49  
Iteration 274: Reward = 1, Total Rewards = 50  
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Iteration 278: Reward = 0, Total Rewards = 50  
Iteration 279: Reward = 1, Total Rewards = 51  
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Iteration 288: Reward = 0, Total Rewards = 53  
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Iteration 290: Reward = 0, Total Rewards = 53  
Iteration 291: Reward = 0, Total Rewards = 53  
Iteration 292: Reward = 0, Total Rewards = 53  
Iteration 293: Reward = 0, Total Rewards = 53  
Iteration 294: Reward = 0, Total Rewards = 53  
Iteration 295: Reward = 0, Total Rewards = 53  
Iteration 296: Reward = 0, Total Rewards = 53  
Iteration 297: Reward = 0, Total Rewards = 53

[illegible]

Iteration 346: Reward = 0, Total Rewards = 58  
Iteration 347: Reward = 0, Total Rewards = 58  
Iteration 348: Reward = 1, Total Rewards = 59  
Iteration 349: Reward = 0, Total Rewards = 59  
Iteration 350: Reward = 0, Total Rewards = 59  
Iteration 351: Reward = 0, Total Rewards = 59  
Iteration 352: Reward = 1, Total Rewards = 60  
Iteration 353: Reward = 0, Total Rewards = 60  
Iteration 354: Reward = 0, Total Rewards = 60  
Iteration 355: Reward = 1, Total Rewards = 61  
Iteration 356: Reward = 0, Total Rewards = 61  
Iteration 357: Reward = 0, Total Rewards = 61  
Iteration 358: Reward = 0, Total Rewards = 61  
Iteration 359: Reward = 0, Total Rewards = 61  
Iteration 360: Reward = 0, Total Rewards = 61  
Iteration 361: Reward = 0, Total Rewards = 61  
Iteration 362: Reward = 1, Total Rewards = 62  
Iteration 363: Reward = 0, Total Rewards = 62  
Iteration 364: Reward = 0, Total Rewards = 62  
Iteration 365: Reward = 0, Total Rewards = 62  
Iteration 366: Reward = 0, Total Rewards = 62  
Iteration 367: Reward = 0, Total Rewards = 62  
Iteration 368: Reward = 0, Total Rewards = 62  
Iteration 369: Reward = 0, Total Rewards = 62  
Iteration 370: Reward = 0, Total Rewards = 62  
Iteration 371: Reward = 0, Total Rewards = 62  
Iteration 372: Reward = 0, Total Rewards = 62  
Iteration 373: Reward = 0, Total Rewards = 62  
Iteration 374: Reward = 0, Total Rewards = 62  
Iteration 375: Reward = 1, Total Rewards = 63  
Iteration 376: Reward = 1, Total Rewards = 64  
Iteration 377: Reward = 0, Total Rewards = 64  
Iteration 378: Reward = 0, Total Rewards = 64  
Iteration 379: Reward = 0, Total Rewards = 64  
Iteration 380: Reward = 0, Total Rewards = 64  
Iteration 381: Reward = 1, Total Rewards = 65  
Iteration 382: Reward = 0, Total Rewards = 65  
Iteration 383: Reward = 0, Total Rewards = 65  
Iteration 384: Reward = 0, Total Rewards = 65  
Iteration 385: Reward = 0, Total Rewards = 65  
Iteration 386: Reward = 1, Total Rewards = 66  
Iteration 387: Reward = 0, Total Rewards = 66  
Iteration 388: Reward = 0, Total Rewards = 66  
Iteration 389: Reward = 0, Total Rewards = 66  
Iteration 390: Reward = 0, Total Rewards = 66  
Iteration 391: Reward = 0, Total Rewards = 66  
Iteration 392: Reward = 0, Total Rewards = 66  
Iteration 393: Reward = 0, Total Rewards = 66

Iteration 394: Reward = 0, Total Rewards = 66  
Iteration 395: Reward = 0, Total Rewards = 66  
Iteration 396: Reward = 0, Total Rewards = 66  
Iteration 397: Reward = 0, Total Rewards = 66  
Iteration 398: Reward = 0, Total Rewards = 66  
Iteration 399: Reward = 0, Total Rewards = 66  
Iteration 400: Reward = 0, Total Rewards = 66  
Iteration 401: Reward = 0, Total Rewards = 66  
Iteration 402: Reward = 0, Total Rewards = 66  
Iteration 403: Reward = 0, Total Rewards = 66  
Iteration 404: Reward = 0, Total Rewards = 66  
Iteration 405: Reward = 0, Total Rewards = 66  
Iteration 406: Reward = 0, Total Rewards = 66  
Iteration 407: Reward = 0, Total Rewards = 66  
Iteration 408: Reward = 0, Total Rewards = 66  
Iteration 409: Reward = 0, Total Rewards = 66  
Iteration 410: Reward = 1, Total Rewards = 67  
Iteration 411: Reward = 0, Total Rewards = 67  
Iteration 412: Reward = 0, Total Rewards = 67  
Iteration 413: Reward = 1, Total Rewards = 68  
Iteration 414: Reward = 0, Total Rewards = 68  
Iteration 415: Reward = 0, Total Rewards = 68  
Iteration 416: Reward = 1, Total Rewards = 69  
Iteration 417: Reward = 0, Total Rewards = 69  
Iteration 418: Reward = 0, Total Rewards = 69  
Iteration 419: Reward = 1, Total Rewards = 70  
Iteration 420: Reward = 0, Total Rewards = 70  
Iteration 421: Reward = 0, Total Rewards = 70  
Iteration 422: Reward = 0, Total Rewards = 70  
Iteration 423: Reward = 0, Total Rewards = 70  
Iteration 424: Reward = 0, Total Rewards = 70  
Iteration 425: Reward = 0, Total Rewards = 70  
Iteration 426: Reward = 0, Total Rewards = 70  
Iteration 427: Reward = 0, Total Rewards = 70  
Iteration 428: Reward = 0, Total Rewards = 70  
Iteration 429: Reward = 1, Total Rewards = 71  
Iteration 430: Reward = 0, Total Rewards = 71  
Iteration 431: Reward = 0, Total Rewards = 71  
Iteration 432: Reward = 1, Total Rewards = 72  
Iteration 433: Reward = 0, Total Rewards = 72  
Iteration 434: Reward = 0, Total Rewards = 72  
Iteration 435: Reward = 0, Total Rewards = 72  
Iteration 436: Reward = 0, Total Rewards = 72  
Iteration 437: Reward = 0, Total Rewards = 72  
Iteration 438: Reward = 1, Total Rewards = 73  
Iteration 439: Reward = 0, Total Rewards = 73  
Iteration 440: Reward = 0, Total Rewards = 73  
Iteration 441: Reward = 0, Total Rewards = 73

Iteration 442: Reward = 1, Total Rewards = 74  
Iteration 443: Reward = 0, Total Rewards = 74  
Iteration 444: Reward = 1, Total Rewards = 75  
Iteration 445: Reward = 0, Total Rewards = 75  
Iteration 446: Reward = 1, Total Rewards = 76  
Iteration 447: Reward = 0, Total Rewards = 76  
Iteration 448: Reward = 0, Total Rewards = 76  
Iteration 449: Reward = 0, Total Rewards = 76  
Iteration 450: Reward = 1, Total Rewards = 77  
Iteration 451: Reward = 0, Total Rewards = 77  
Iteration 452: Reward = 0, Total Rewards = 77  
Iteration 453: Reward = 1, Total Rewards = 78  
Iteration 454: Reward = 0, Total Rewards = 78  
Iteration 455: Reward = 0, Total Rewards = 78  
Iteration 456: Reward = 0, Total Rewards = 78  
Iteration 457: Reward = 0, Total Rewards = 78  
Iteration 458: Reward = 0, Total Rewards = 78  
Iteration 459: Reward = 1, Total Rewards = 79  
Iteration 460: Reward = 0, Total Rewards = 79  
Iteration 461: Reward = 0, Total Rewards = 79  
Iteration 462: Reward = 1, Total Rewards = 80  
Iteration 463: Reward = 0, Total Rewards = 80  
Iteration 464: Reward = 0, Total Rewards = 80  
Iteration 465: Reward = 1, Total Rewards = 81  
Iteration 466: Reward = 0, Total Rewards = 81  
Iteration 467: Reward = 0, Total Rewards = 81  
Iteration 468: Reward = 0, Total Rewards = 81  
Iteration 469: Reward = 0, Total Rewards = 81  
Iteration 470: Reward = 1, Total Rewards = 82  
Iteration 471: Reward = 0, Total Rewards = 82  
Iteration 472: Reward = 1, Total Rewards = 83  
Iteration 473: Reward = 1, Total Rewards = 84  
Iteration 474: Reward = 0, Total Rewards = 84  
Iteration 475: Reward = 0, Total Rewards = 84  
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Iteration 478: Reward = 0, Total Rewards = 85  
Iteration 479: Reward = 0, Total Rewards = 85  
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Iteration 481: Reward = 0, Total Rewards = 85  
Iteration 482: Reward = 0, Total Rewards = 85  
Iteration 483: Reward = 0, Total Rewards = 85  
Iteration 484: Reward = 0, Total Rewards = 85  
Iteration 485: Reward = 1, Total Rewards = 86  
Iteration 486: Reward = 0, Total Rewards = 86  
Iteration 487: Reward = 0, Total Rewards = 86  
Iteration 488: Reward = 1, Total Rewards = 87  
Iteration 489: Reward = 0, Total Rewards = 87

Iteration 490: Reward = 0, Total Rewards = 87  
Iteration 491: Reward = 1, Total Rewards = 88  
Iteration 492: Reward = 1, Total Rewards = 89  
Iteration 493: Reward = 0, Total Rewards = 89  
Iteration 494: Reward = 0, Total Rewards = 89  
Iteration 495: Reward = 0, Total Rewards = 89  
Iteration 496: Reward = 0, Total Rewards = 89  
Iteration 497: Reward = 0, Total Rewards = 89  
Iteration 498: Reward = 1, Total Rewards = 90  
Iteration 499: Reward = 0, Total Rewards = 90  
Iteration 500: Reward = 0, Total Rewards = 90  
Iteration 501: Reward = 1, Total Rewards = 91  
Iteration 502: Reward = 0, Total Rewards = 91  
Iteration 503: Reward = 0, Total Rewards = 91  
Iteration 504: Reward = 0, Total Rewards = 91  
Iteration 505: Reward = 0, Total Rewards = 91  
Iteration 506: Reward = 0, Total Rewards = 91  
Iteration 507: Reward = 0, Total Rewards = 91  
Iteration 508: Reward = 0, Total Rewards = 91  
Iteration 509: Reward = 0, Total Rewards = 91  
Iteration 510: Reward = 0, Total Rewards = 91  
Iteration 511: Reward = 1, Total Rewards = 92  
Iteration 512: Reward = 0, Total Rewards = 92  
Iteration 513: Reward = 0, Total Rewards = 92  
Iteration 514: Reward = 0, Total Rewards = 92  
Iteration 515: Reward = 0, Total Rewards = 92  
Iteration 516: Reward = 0, Total Rewards = 92  
Iteration 517: Reward = 0, Total Rewards = 92  
Iteration 518: Reward = 0, Total Rewards = 92  
Iteration 519: Reward = 0, Total Rewards = 92  
Iteration 520: Reward = 0, Total Rewards = 92  
Iteration 521: Reward = 0, Total Rewards = 92  
Iteration 522: Reward = 0, Total Rewards = 92  
Iteration 523: Reward = 0, Total Rewards = 92  
Iteration 524: Reward = 0, Total Rewards = 92  
Iteration 525: Reward = 0, Total Rewards = 92  
Iteration 526: Reward = 0, Total Rewards = 92  
Iteration 527: Reward = 0, Total Rewards = 92  
Iteration 528: Reward = 0, Total Rewards = 92  
Iteration 529: Reward = 1, Total Rewards = 93  
Iteration 530: Reward = 0, Total Rewards = 93  
Iteration 531: Reward = 1, Total Rewards = 94  
Iteration 532: Reward = 0, Total Rewards = 94  
Iteration 533: Reward = 0, Total Rewards = 94  
Iteration 534: Reward = 0, Total Rewards = 94  
Iteration 535: Reward = 0, Total Rewards = 94  
Iteration 536: Reward = 0, Total Rewards = 94  
Iteration 537: Reward = 0, Total Rewards = 94





Iteration 586: Reward = 0, Total Rewards = 97  
Iteration 587: Reward = 1, Total Rewards = 98  
Iteration 588: Reward = 1, Total Rewards = 99  
Iteration 589: Reward = 0, Total Rewards = 99  
Iteration 590: Reward = 1, Total Rewards = 100  
Iteration 591: Reward = 0, Total Rewards = 100  
Iteration 592: Reward = 0, Total Rewards = 100  
Iteration 593: Reward = 1, Total Rewards = 101  
Iteration 594: Reward = 1, Total Rewards = 102  
Iteration 595: Reward = 0, Total Rewards = 102  
Iteration 596: Reward = 0, Total Rewards = 102  
Iteration 597: Reward = 0, Total Rewards = 102  
Iteration 598: Reward = 0, Total Rewards = 102  
Iteration 599: Reward = 0, Total Rewards = 102  
Iteration 600: Reward = 0, Total Rewards = 102  
Iteration 601: Reward = 0, Total Rewards = 102  
Iteration 602: Reward = 0, Total Rewards = 102  
Iteration 603: Reward = 1, Total Rewards = 103  
Iteration 604: Reward = 0, Total Rewards = 103  
Iteration 605: Reward = 1, Total Rewards = 104  
Iteration 606: Reward = 0, Total Rewards = 104  
Iteration 607: Reward = 0, Total Rewards = 104  
Iteration 608: Reward = 0, Total Rewards = 104  
Iteration 609: Reward = 0, Total Rewards = 104  
Iteration 610: Reward = 0, Total Rewards = 104  
Iteration 611: Reward = 0, Total Rewards = 104  
Iteration 612: Reward = 0, Total Rewards = 104  
Iteration 613: Reward = 0, Total Rewards = 104  
Iteration 614: Reward = 0, Total Rewards = 104  
Iteration 615: Reward = 0, Total Rewards = 104  
Iteration 616: Reward = 0, Total Rewards = 104  
Iteration 617: Reward = 1, Total Rewards = 105  
Iteration 618: Reward = 0, Total Rewards = 105  
Iteration 619: Reward = 0, Total Rewards = 105  
Iteration 620: Reward = 0, Total Rewards = 105  
Iteration 621: Reward = 0, Total Rewards = 105  
Iteration 622: Reward = 0, Total Rewards = 105  
Iteration 623: Reward = 0, Total Rewards = 105  
Iteration 624: Reward = 0, Total Rewards = 105  
Iteration 625: Reward = 1, Total Rewards = 106  
Iteration 626: Reward = 0, Total Rewards = 106  
Iteration 627: Reward = 0, Total Rewards = 106  
Iteration 628: Reward = 0, Total Rewards = 106  
Iteration 629: Reward = 0, Total Rewards = 106  
Iteration 630: Reward = 0, Total Rewards = 106  
Iteration 631: Reward = 0, Total Rewards = 106  
Iteration 632: Reward = 1, Total Rewards = 107  
Iteration 633: Reward = 0, Total Rewards = 107

Iteration 634: Reward = 0, Total Rewards = 107  
Iteration 635: Reward = 0, Total Rewards = 107  
Iteration 636: Reward = 0, Total Rewards = 107  
Iteration 637: Reward = 0, Total Rewards = 107  
Iteration 638: Reward = 0, Total Rewards = 107  
Iteration 639: Reward = 0, Total Rewards = 107  
Iteration 640: Reward = 0, Total Rewards = 107  
Iteration 641: Reward = 1, Total Rewards = 108  
Iteration 642: Reward = 0, Total Rewards = 108  
Iteration 643: Reward = 0, Total Rewards = 108  
Iteration 644: Reward = 0, Total Rewards = 108  
Iteration 645: Reward = 0, Total Rewards = 108  
Iteration 646: Reward = 0, Total Rewards = 108  
Iteration 647: Reward = 0, Total Rewards = 108  
Iteration 648: Reward = 1, Total Rewards = 109  
Iteration 649: Reward = 0, Total Rewards = 109  
Iteration 650: Reward = 1, Total Rewards = 110  
Iteration 651: Reward = 0, Total Rewards = 110  
Iteration 652: Reward = 0, Total Rewards = 110  
Iteration 653: Reward = 0, Total Rewards = 110  
Iteration 654: Reward = 1, Total Rewards = 111  
Iteration 655: Reward = 0, Total Rewards = 111  
Iteration 656: Reward = 0, Total Rewards = 111  
Iteration 657: Reward = 0, Total Rewards = 111  
Iteration 658: Reward = 0, Total Rewards = 111  
Iteration 659: Reward = 0, Total Rewards = 111  
Iteration 660: Reward = 0, Total Rewards = 111  
Iteration 661: Reward = 0, Total Rewards = 111  
Iteration 662: Reward = 0, Total Rewards = 111  
Iteration 663: Reward = 0, Total Rewards = 111  
Iteration 664: Reward = 0, Total Rewards = 111  
Iteration 665: Reward = 0, Total Rewards = 111  
Iteration 666: Reward = 0, Total Rewards = 111  
Iteration 667: Reward = 0, Total Rewards = 111  
Iteration 668: Reward = 0, Total Rewards = 111  
Iteration 669: Reward = 0, Total Rewards = 111  
Iteration 670: Reward = 0, Total Rewards = 111  
Iteration 671: Reward = 0, Total Rewards = 111  
Iteration 672: Reward = 0, Total Rewards = 111  
Iteration 673: Reward = 0, Total Rewards = 111  
Iteration 674: Reward = 0, Total Rewards = 111  
Iteration 675: Reward = 1, Total Rewards = 112  
Iteration 676: Reward = 0, Total Rewards = 112  
Iteration 677: Reward = 0, Total Rewards = 112  
Iteration 678: Reward = 0, Total Rewards = 112  
Iteration 679: Reward = 0, Total Rewards = 112  
Iteration 680: Reward = 0, Total Rewards = 112  
Iteration 681: Reward = 0, Total Rewards = 112

Iteration 682: Reward = 1, Total Rewards = 113  
Iteration 683: Reward = 0, Total Rewards = 113  
Iteration 684: Reward = 0, Total Rewards = 113  
Iteration 685: Reward = 0, Total Rewards = 113  
Iteration 686: Reward = 0, Total Rewards = 113  
Iteration 687: Reward = 1, Total Rewards = 114  
Iteration 688: Reward = 0, Total Rewards = 114  
Iteration 689: Reward = 0, Total Rewards = 114  
Iteration 690: Reward = 0, Total Rewards = 114  
Iteration 691: Reward = 0, Total Rewards = 114  
Iteration 692: Reward = 0, Total Rewards = 114  
Iteration 693: Reward = 0, Total Rewards = 114  
Iteration 694: Reward = 0, Total Rewards = 114  
Iteration 695: Reward = 1, Total Rewards = 115  
Iteration 696: Reward = 1, Total Rewards = 116  
Iteration 697: Reward = 0, Total Rewards = 116  
Iteration 698: Reward = 0, Total Rewards = 116  
Iteration 699: Reward = 0, Total Rewards = 116  
Iteration 700: Reward = 0, Total Rewards = 116  
Iteration 701: Reward = 1, Total Rewards = 117  
Iteration 702: Reward = 0, Total Rewards = 117  
Iteration 703: Reward = 0, Total Rewards = 117  
Iteration 704: Reward = 0, Total Rewards = 117  
Iteration 705: Reward = 0, Total Rewards = 117  
Iteration 706: Reward = 0, Total Rewards = 117  
Iteration 707: Reward = 0, Total Rewards = 117  
Iteration 708: Reward = 1, Total Rewards = 118  
Iteration 709: Reward = 1, Total Rewards = 119  
Iteration 710: Reward = 0, Total Rewards = 119  
Iteration 711: Reward = 0, Total Rewards = 119  
Iteration 712: Reward = 0, Total Rewards = 119  
Iteration 713: Reward = 0, Total Rewards = 119  
Iteration 714: Reward = 1, Total Rewards = 120  
Iteration 715: Reward = 0, Total Rewards = 120  
Iteration 716: Reward = 1, Total Rewards = 121  
Iteration 717: Reward = 1, Total Rewards = 122  
Iteration 718: Reward = 0, Total Rewards = 122  
Iteration 719: Reward = 0, Total Rewards = 122  
Iteration 720: Reward = 0, Total Rewards = 122  
Iteration 721: Reward = 0, Total Rewards = 122  
Iteration 722: Reward = 0, Total Rewards = 122  
Iteration 723: Reward = 0, Total Rewards = 122  
Iteration 724: Reward = 1, Total Rewards = 123  
Iteration 725: Reward = 0, Total Rewards = 123  
Iteration 726: Reward = 0, Total Rewards = 123  
Iteration 727: Reward = 0, Total Rewards = 123  
Iteration 728: Reward = 0, Total Rewards = 123  
Iteration 729: Reward = 0, Total Rewards = 123

Iteration 730: Reward = 0, Total Rewards = 123  
Iteration 731: Reward = 0, Total Rewards = 123  
Iteration 732: Reward = 0, Total Rewards = 123  
Iteration 733: Reward = 0, Total Rewards = 123  
Iteration 734: Reward = 0, Total Rewards = 123  
Iteration 735: Reward = 0, Total Rewards = 123  
Iteration 736: Reward = 0, Total Rewards = 123  
Iteration 737: Reward = 0, Total Rewards = 123  
Iteration 738: Reward = 0, Total Rewards = 123  
Iteration 739: Reward = 0, Total Rewards = 123  
Iteration 740: Reward = 0, Total Rewards = 123  
Iteration 741: Reward = 0, Total Rewards = 123  
Iteration 742: Reward = 0, Total Rewards = 123  
Iteration 743: Reward = 0, Total Rewards = 123  
Iteration 744: Reward = 0, Total Rewards = 123  
Iteration 745: Reward = 1, Total Rewards = 124  
Iteration 746: Reward = 1, Total Rewards = 125  
Iteration 747: Reward = 0, Total Rewards = 125  
Iteration 748: Reward = 0, Total Rewards = 125  
Iteration 749: Reward = 1, Total Rewards = 126  
Iteration 750: Reward = 0, Total Rewards = 126  
Iteration 751: Reward = 0, Total Rewards = 126  
Iteration 752: Reward = 0, Total Rewards = 126  
Iteration 753: Reward = 0, Total Rewards = 126  
Iteration 754: Reward = 1, Total Rewards = 127  
Iteration 755: Reward = 0, Total Rewards = 127  
Iteration 756: Reward = 1, Total Rewards = 128  
Iteration 757: Reward = 0, Total Rewards = 128  
Iteration 758: Reward = 0, Total Rewards = 128  
Iteration 759: Reward = 1, Total Rewards = 129  
Iteration 760: Reward = 0, Total Rewards = 129  
Iteration 761: Reward = 1, Total Rewards = 130  
Iteration 762: Reward = 1, Total Rewards = 131  
Iteration 763: Reward = 0, Total Rewards = 131  
Iteration 764: Reward = 0, Total Rewards = 131  
Iteration 765: Reward = 0, Total Rewards = 131  
Iteration 766: Reward = 0, Total Rewards = 131  
Iteration 767: Reward = 0, Total Rewards = 131  
Iteration 768: Reward = 0, Total Rewards = 131  
Iteration 769: Reward = 0, Total Rewards = 131  
Iteration 770: Reward = 0, Total Rewards = 131  
Iteration 771: Reward = 0, Total Rewards = 131  
Iteration 772: Reward = 1, Total Rewards = 132  
Iteration 773: Reward = 0, Total Rewards = 132  
Iteration 774: Reward = 0, Total Rewards = 132  
Iteration 775: Reward = 0, Total Rewards = 132  
Iteration 776: Reward = 0, Total Rewards = 132  
Iteration 777: Reward = 0, Total Rewards = 132

[illegible]

Iteration 826: Reward = 0, Total Rewards = 136  
Iteration 827: Reward = 0, Total Rewards = 136  
Iteration 828: Reward = 0, Total Rewards = 136  
Iteration 829: Reward = 0, Total Rewards = 136  
Iteration 830: Reward = 0, Total Rewards = 136  
Iteration 831: Reward = 0, Total Rewards = 136  
Iteration 832: Reward = 0, Total Rewards = 136  
Iteration 833: Reward = 1, Total Rewards = 137  
Iteration 834: Reward = 0, Total Rewards = 137  
Iteration 835: Reward = 0, Total Rewards = 137  
Iteration 836: Reward = 0, Total Rewards = 137  
Iteration 837: Reward = 0, Total Rewards = 137  
Iteration 838: Reward = 0, Total Rewards = 137  
Iteration 839: Reward = 0, Total Rewards = 137  
Iteration 840: Reward = 0, Total Rewards = 137  
Iteration 841: Reward = 0, Total Rewards = 137  
Iteration 842: Reward = 1, Total Rewards = 138  
Iteration 843: Reward = 0, Total Rewards = 138  
Iteration 844: Reward = 0, Total Rewards = 138  
Iteration 845: Reward = 0, Total Rewards = 138  
Iteration 846: Reward = 0, Total Rewards = 138  
Iteration 847: Reward = 0, Total Rewards = 138  
Iteration 848: Reward = 0, Total Rewards = 138  
Iteration 849: Reward = 1, Total Rewards = 139  
Iteration 850: Reward = 0, Total Rewards = 139  
Iteration 851: Reward = 0, Total Rewards = 139  
Iteration 852: Reward = 0, Total Rewards = 139  
Iteration 853: Reward = 1, Total Rewards = 140  
Iteration 854: Reward = 0, Total Rewards = 140  
Iteration 855: Reward = 0, Total Rewards = 140  
Iteration 856: Reward = 0, Total Rewards = 140  
Iteration 857: Reward = 0, Total Rewards = 140  
Iteration 858: Reward = 1, Total Rewards = 141  
Iteration 859: Reward = 0, Total Rewards = 141  
Iteration 860: Reward = 1, Total Rewards = 142  
Iteration 861: Reward = 0, Total Rewards = 142  
Iteration 862: Reward = 0, Total Rewards = 142  
Iteration 863: Reward = 0, Total Rewards = 142  
Iteration 864: Reward = 1, Total Rewards = 143  
Iteration 865: Reward = 1, Total Rewards = 144  
Iteration 866: Reward = 0, Total Rewards = 144  
Iteration 867: Reward = 0, Total Rewards = 144  
Iteration 868: Reward = 0, Total Rewards = 144  
Iteration 869: Reward = 0, Total Rewards = 144  
Iteration 870: Reward = 0, Total Rewards = 144  
Iteration 871: Reward = 0, Total Rewards = 144  
Iteration 872: Reward = 0, Total Rewards = 144  
Iteration 873: Reward = 1, Total Rewards = 145

[illegible]



[illegible]

```

Iteration 970: Reward = 0, Total Rewards = 151
Iteration 971: Reward = 1, Total Rewards = 152
Iteration 972: Reward = 0, Total Rewards = 152
Iteration 973: Reward = 0, Total Rewards = 152
Iteration 974: Reward = 0, Total Rewards = 152
Iteration 975: Reward = 0, Total Rewards = 152
Iteration 976: Reward = 0, Total Rewards = 152
Iteration 977: Reward = 0, Total Rewards = 152
Iteration 978: Reward = 0, Total Rewards = 152
Iteration 979: Reward = 0, Total Rewards = 152
Iteration 980: Reward = 1, Total Rewards = 153
Iteration 981: Reward = 1, Total Rewards = 154
Iteration 982: Reward = 0, Total Rewards = 154
Iteration 983: Reward = 0, Total Rewards = 154
Iteration 984: Reward = 1, Total Rewards = 155
Iteration 985: Reward = 0, Total Rewards = 155
Iteration 986: Reward = 0, Total Rewards = 155
Iteration 987: Reward = 0, Total Rewards = 155
Iteration 988: Reward = 1, Total Rewards = 156
Iteration 989: Reward = 0, Total Rewards = 156
Iteration 990: Reward = 1, Total Rewards = 157
Iteration 991: Reward = 1, Total Rewards = 158
Iteration 992: Reward = 0, Total Rewards = 158
Iteration 993: Reward = 0, Total Rewards = 158
Iteration 994: Reward = 0, Total Rewards = 158
Iteration 995: Reward = 0, Total Rewards = 158
Iteration 996: Reward = 1, Total Rewards = 159
Iteration 997: Reward = 0, Total Rewards = 159
Iteration 998: Reward = 1, Total Rewards = 160
Iteration 999: Reward = 0, Total Rewards = 160
Iteration 1000: Reward = 1, Total Rewards = 161
Total Rewards from Random Policy: 161

```

## 10 Using Greedy Policy (0.5M)

Print all the iterations with random policy selected for the given Ad. (Mandatory)

```

[50]: # run the environment with an agent that is guided by a greedy policy
      #-----write your code below this line-----
      def greedy_policy(env, iterations, epsilon):
          """
          Implements a greedy policy for selecting arms (ads) in the environment with
          epsilon-greedy exploration.

          Parameters:
          - env (CTREnvironment): The environment object containing ads and their
          probabilities.
          """

```

- *iterations (int): Number of iterations (rounds) to run the policy.*
- *epsilon (float): Exploration-exploitation trade-off parameter (0 to 1).*

*Returns:*

- *list: List of total rewards accumulated after each iteration.*

"""

```
total_rewards = [] # List to store cumulative rewards after each iteration
rewards = [] # List to store rewards obtained in each iteration
```

```
for i in range(iterations):
    if np.random.random() > epsilon: # Exploit: choose the arm with
    ↪highest estimated value
        arm = np.argmax(env.values)
    else: # Explore: choose a random arm
        arm = np.random.randint(env.n_arms)

    reward = env.select_arm(arm) # Get reward for selecting the arm
    rewards.append(reward) # Append reward to the list of rewards
    total_rewards.append(sum(rewards)) # Append cumulative total rewards
    print(f"Iteration {i+1}: Reward = {reward}, Total Rewards =
    ↪{total_rewards[-1]}") # Print iteration details

    return total_rewards # Return list of total rewards accumulated

epsilon = 0.1 # Exploration-exploitation trade-off parameter
env.reset() # Reset the environment
greedy_rewards = greedy_policy(env, 1000, epsilon) # Execute greedy policy for
    ↪1000 iterations with epsilon
print("Total Rewards from Greedy Policy:", greedy_rewards[-1]) # Print total
    ↪rewards accumulated
```

```
Iteration 1: Reward = 0, Total Rewards = 0
Iteration 2: Reward = 0, Total Rewards = 0
Iteration 3: Reward = 0, Total Rewards = 0
Iteration 4: Reward = 0, Total Rewards = 0
Iteration 5: Reward = 0, Total Rewards = 0
Iteration 6: Reward = 0, Total Rewards = 0
Iteration 7: Reward = 0, Total Rewards = 0
Iteration 8: Reward = 1, Total Rewards = 1
Iteration 9: Reward = 0, Total Rewards = 1
Iteration 10: Reward = 0, Total Rewards = 1
Iteration 11: Reward = 0, Total Rewards = 1
Iteration 12: Reward = 0, Total Rewards = 1
Iteration 13: Reward = 1, Total Rewards = 2
Iteration 14: Reward = 0, Total Rewards = 2
Iteration 15: Reward = 1, Total Rewards = 3
Iteration 16: Reward = 1, Total Rewards = 4
```

Iteration 17: Reward = 0, Total Rewards = 4  
Iteration 18: Reward = 0, Total Rewards = 4  
Iteration 19: Reward = 1, Total Rewards = 5  
Iteration 20: Reward = 0, Total Rewards = 5  
Iteration 21: Reward = 0, Total Rewards = 5  
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Iteration 963: Reward = 0, Total Rewards = 439  
Iteration 964: Reward = 0, Total Rewards = 439  
Iteration 965: Reward = 1, Total Rewards = 440  
Iteration 966: Reward = 1, Total Rewards = 441  
Iteration 967: Reward = 0, Total Rewards = 441  
Iteration 968: Reward = 1, Total Rewards = 442  
Iteration 969: Reward = 1, Total Rewards = 443  
Iteration 970: Reward = 0, Total Rewards = 443  
Iteration 971: Reward = 0, Total Rewards = 443  
Iteration 972: Reward = 0, Total Rewards = 443  
Iteration 973: Reward = 0, Total Rewards = 443  
Iteration 974: Reward = 1, Total Rewards = 444  
Iteration 975: Reward = 0, Total Rewards = 444  
Iteration 976: Reward = 0, Total Rewards = 444

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Iteration 977: Reward = 0, Total Rewards = 444
Iteration 978: Reward = 1, Total Rewards = 445
Iteration 979: Reward = 0, Total Rewards = 445
Iteration 980: Reward = 1, Total Rewards = 446
Iteration 981: Reward = 0, Total Rewards = 446
Iteration 982: Reward = 1, Total Rewards = 447
Iteration 983: Reward = 0, Total Rewards = 447
Iteration 984: Reward = 1, Total Rewards = 448
Iteration 985: Reward = 0, Total Rewards = 448
Iteration 986: Reward = 1, Total Rewards = 449
Iteration 987: Reward = 1, Total Rewards = 450
Iteration 988: Reward = 0, Total Rewards = 450
Iteration 989: Reward = 1, Total Rewards = 451
Iteration 990: Reward = 0, Total Rewards = 451
Iteration 991: Reward = 1, Total Rewards = 452
Iteration 992: Reward = 1, Total Rewards = 453
Iteration 993: Reward = 1, Total Rewards = 454
Iteration 994: Reward = 0, Total Rewards = 454
Iteration 995: Reward = 1, Total Rewards = 455
Iteration 996: Reward = 1, Total Rewards = 456
Iteration 997: Reward = 0, Total Rewards = 456
Iteration 998: Reward = 0, Total Rewards = 456
Iteration 999: Reward = 0, Total Rewards = 456
Iteration 1000: Reward = 1, Total Rewards = 457
Total Rewards from Greedy Policy: 457

```

## 11 Using Epsilon-Greedy Policy (0.5M)

Print all the iterations with random policy selected for the given Ad. (Mandatory)

```

[51]: # run the environment with an agent that is guided by a epsilon-greedy policy
#-----write your code below this line-----

def epsilon_greedy_policy(env, iterations, epsilon=0.1):
    """
    Implements an epsilon-greedy policy for selecting arms (ads) in the
    ↪environment.

    Parameters:
    - env (CTREnvironment): The environment object containing ads and their
    ↪probabilities.
    - iterations (int): Number of iterations (rounds) to run the policy.
    - epsilon (float, optional): Exploration-exploitation trade-off parameter
    ↪(default: 0.1).

    Returns:
    - list: List of total rewards accumulated after each iteration.
    """

```



```

"""
total_rewards = [] # List to store cumulative rewards after each iteration
rewards = [] # List to store rewards obtained in each iteration

for i in range(iterations):
    if np.random.random() > epsilon: # Exploit: choose the arm with
↳highest estimated value
        arm = np.argmax(env.values)
    else: # Explore: choose a random arm
        arm = np.random.randint(env.n_arms)

    reward = env.select_arm(arm) # Get reward for selecting the arm
    rewards.append(reward) # Append reward to the list of rewards
    total_rewards.append(sum(rewards)) # Append cumulative total rewards
    print(f"Iteration {i+1}: Reward = {reward}, Total Rewards =
↳{total_rewards[-1]}") # Print iteration details

    return total_rewards # Return list of total rewards accumulated

env.reset() # Reset the environment
epsilon_greedy_rewards = epsilon_greedy_policy(env, 1000) # Execute
↳epsilon-greedy policy for 1000 iterations
print("Total Rewards from Epsilon-Greedy Policy:", epsilon_greedy_rewards[-1])
↳# Print total rewards accumulated

```

```

Iteration 1: Reward = 0, Total Rewards = 0
Iteration 2: Reward = 0, Total Rewards = 0
Iteration 3: Reward = 0, Total Rewards = 0
Iteration 4: Reward = 0, Total Rewards = 0
Iteration 5: Reward = 0, Total Rewards = 0
Iteration 6: Reward = 0, Total Rewards = 0
Iteration 7: Reward = 0, Total Rewards = 0
Iteration 8: Reward = 0, Total Rewards = 0
Iteration 9: Reward = 0, Total Rewards = 0
Iteration 10: Reward = 0, Total Rewards = 0
Iteration 11: Reward = 0, Total Rewards = 0
Iteration 12: Reward = 0, Total Rewards = 0
Iteration 13: Reward = 0, Total Rewards = 0
Iteration 14: Reward = 0, Total Rewards = 0
Iteration 15: Reward = 0, Total Rewards = 0
Iteration 16: Reward = 1, Total Rewards = 1
Iteration 17: Reward = 0, Total Rewards = 1
Iteration 18: Reward = 0, Total Rewards = 1
Iteration 19: Reward = 0, Total Rewards = 1
Iteration 20: Reward = 0, Total Rewards = 1
Iteration 21: Reward = 0, Total Rewards = 1
Iteration 22: Reward = 0, Total Rewards = 1

```

[illegible]

Iteration 71: Reward = 0, Total Rewards = 1  
Iteration 72: Reward = 0, Total Rewards = 1  
Iteration 73: Reward = 0, Total Rewards = 1  
Iteration 74: Reward = 0, Total Rewards = 1  
Iteration 75: Reward = 0, Total Rewards = 1  
Iteration 76: Reward = 0, Total Rewards = 1  
Iteration 77: Reward = 0, Total Rewards = 1  
Iteration 78: Reward = 0, Total Rewards = 1  
Iteration 79: Reward = 0, Total Rewards = 1  
Iteration 80: Reward = 0, Total Rewards = 1  
Iteration 81: Reward = 0, Total Rewards = 1  
Iteration 82: Reward = 0, Total Rewards = 1  
Iteration 83: Reward = 0, Total Rewards = 1  
Iteration 84: Reward = 0, Total Rewards = 1  
Iteration 85: Reward = 0, Total Rewards = 1  
Iteration 86: Reward = 0, Total Rewards = 1  
Iteration 87: Reward = 0, Total Rewards = 1  
Iteration 88: Reward = 0, Total Rewards = 1  
Iteration 89: Reward = 0, Total Rewards = 1  
Iteration 90: Reward = 0, Total Rewards = 1  
Iteration 91: Reward = 0, Total Rewards = 1  
Iteration 92: Reward = 0, Total Rewards = 1  
Iteration 93: Reward = 0, Total Rewards = 1  
Iteration 94: Reward = 0, Total Rewards = 1  
Iteration 95: Reward = 0, Total Rewards = 1  
Iteration 96: Reward = 0, Total Rewards = 1  
Iteration 97: Reward = 0, Total Rewards = 1  
Iteration 98: Reward = 0, Total Rewards = 1  
Iteration 99: Reward = 0, Total Rewards = 1  
Iteration 100: Reward = 0, Total Rewards = 1  
Iteration 101: Reward = 1, Total Rewards = 2  
Iteration 102: Reward = 1, Total Rewards = 3  
Iteration 103: Reward = 0, Total Rewards = 3  
Iteration 104: Reward = 1, Total Rewards = 4  
Iteration 105: Reward = 1, Total Rewards = 5  
Iteration 106: Reward = 1, Total Rewards = 6  
Iteration 107: Reward = 0, Total Rewards = 6  
Iteration 108: Reward = 1, Total Rewards = 7  
Iteration 109: Reward = 1, Total Rewards = 8  
Iteration 110: Reward = 0, Total Rewards = 8  
Iteration 111: Reward = 0, Total Rewards = 8  
Iteration 112: Reward = 0, Total Rewards = 8  
Iteration 113: Reward = 1, Total Rewards = 9  
Iteration 114: Reward = 0, Total Rewards = 9  
Iteration 115: Reward = 1, Total Rewards = 10  
Iteration 116: Reward = 1, Total Rewards = 11  
Iteration 117: Reward = 0, Total Rewards = 11  
Iteration 118: Reward = 1, Total Rewards = 12

Iteration 119: Reward = 1, Total Rewards = 13  
Iteration 120: Reward = 1, Total Rewards = 14  
Iteration 121: Reward = 0, Total Rewards = 14  
Iteration 122: Reward = 0, Total Rewards = 14  
Iteration 123: Reward = 0, Total Rewards = 14  
Iteration 124: Reward = 1, Total Rewards = 15  
Iteration 125: Reward = 0, Total Rewards = 15  
Iteration 126: Reward = 0, Total Rewards = 15  
Iteration 127: Reward = 1, Total Rewards = 16  
Iteration 128: Reward = 1, Total Rewards = 17  
Iteration 129: Reward = 1, Total Rewards = 18  
Iteration 130: Reward = 0, Total Rewards = 18  
Iteration 131: Reward = 1, Total Rewards = 19  
Iteration 132: Reward = 1, Total Rewards = 20  
Iteration 133: Reward = 0, Total Rewards = 20  
Iteration 134: Reward = 1, Total Rewards = 21  
Iteration 135: Reward = 0, Total Rewards = 21  
Iteration 136: Reward = 0, Total Rewards = 21  
Iteration 137: Reward = 0, Total Rewards = 21  
Iteration 138: Reward = 1, Total Rewards = 22  
Iteration 139: Reward = 0, Total Rewards = 22  
Iteration 140: Reward = 1, Total Rewards = 23  
Iteration 141: Reward = 1, Total Rewards = 24  
Iteration 142: Reward = 0, Total Rewards = 24  
Iteration 143: Reward = 0, Total Rewards = 24  
Iteration 144: Reward = 0, Total Rewards = 24  
Iteration 145: Reward = 0, Total Rewards = 24  
Iteration 146: Reward = 0, Total Rewards = 24  
Iteration 147: Reward = 1, Total Rewards = 25  
Iteration 148: Reward = 0, Total Rewards = 25  
Iteration 149: Reward = 1, Total Rewards = 26  
Iteration 150: Reward = 0, Total Rewards = 26  
Iteration 151: Reward = 0, Total Rewards = 26  
Iteration 152: Reward = 1, Total Rewards = 27  
Iteration 153: Reward = 1, Total Rewards = 28  
Iteration 154: Reward = 0, Total Rewards = 28  
Iteration 155: Reward = 1, Total Rewards = 29  
Iteration 156: Reward = 1, Total Rewards = 30  
Iteration 157: Reward = 0, Total Rewards = 30  
Iteration 158: Reward = 0, Total Rewards = 30  
Iteration 159: Reward = 0, Total Rewards = 30  
Iteration 160: Reward = 1, Total Rewards = 31  
Iteration 161: Reward = 1, Total Rewards = 32  
Iteration 162: Reward = 0, Total Rewards = 32  
Iteration 163: Reward = 1, Total Rewards = 33  
Iteration 164: Reward = 1, Total Rewards = 34  
Iteration 165: Reward = 1, Total Rewards = 35  
Iteration 166: Reward = 0, Total Rewards = 35

Iteration 167: Reward = 0, Total Rewards = 35  
Iteration 168: Reward = 1, Total Rewards = 36  
Iteration 169: Reward = 0, Total Rewards = 36  
Iteration 170: Reward = 0, Total Rewards = 36  
Iteration 171: Reward = 1, Total Rewards = 37  
Iteration 172: Reward = 0, Total Rewards = 37  
Iteration 173: Reward = 0, Total Rewards = 37  
Iteration 174: Reward = 0, Total Rewards = 37  
Iteration 175: Reward = 0, Total Rewards = 37  
Iteration 176: Reward = 1, Total Rewards = 38  
Iteration 177: Reward = 1, Total Rewards = 39  
Iteration 178: Reward = 0, Total Rewards = 39  
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Iteration 184: Reward = 0, Total Rewards = 40  
Iteration 185: Reward = 0, Total Rewards = 40  
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Iteration 195: Reward = 0, Total Rewards = 42  
Iteration 196: Reward = 1, Total Rewards = 43  
Iteration 197: Reward = 0, Total Rewards = 43  
Iteration 198: Reward = 0, Total Rewards = 43  
Iteration 199: Reward = 1, Total Rewards = 44  
Iteration 200: Reward = 1, Total Rewards = 45  
Iteration 201: Reward = 0, Total Rewards = 45  
Iteration 202: Reward = 0, Total Rewards = 45  
Iteration 203: Reward = 0, Total Rewards = 45  
Iteration 204: Reward = 0, Total Rewards = 45  
Iteration 205: Reward = 0, Total Rewards = 45  
Iteration 206: Reward = 0, Total Rewards = 45  
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Iteration 209: Reward = 1, Total Rewards = 46  
Iteration 210: Reward = 0, Total Rewards = 46  
Iteration 211: Reward = 1, Total Rewards = 47  
Iteration 212: Reward = 0, Total Rewards = 47  
Iteration 213: Reward = 1, Total Rewards = 48  
Iteration 214: Reward = 0, Total Rewards = 48

Iteration 215: Reward = 1, Total Rewards = 49  
Iteration 216: Reward = 1, Total Rewards = 50  
Iteration 217: Reward = 0, Total Rewards = 50  
Iteration 218: Reward = 0, Total Rewards = 50  
Iteration 219: Reward = 0, Total Rewards = 50  
Iteration 220: Reward = 0, Total Rewards = 50  
Iteration 221: Reward = 1, Total Rewards = 51  
Iteration 222: Reward = 1, Total Rewards = 52  
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Iteration 224: Reward = 1, Total Rewards = 53  
Iteration 225: Reward = 0, Total Rewards = 53  
Iteration 226: Reward = 1, Total Rewards = 54  
Iteration 227: Reward = 1, Total Rewards = 55  
Iteration 228: Reward = 1, Total Rewards = 56  
Iteration 229: Reward = 0, Total Rewards = 56  
Iteration 230: Reward = 1, Total Rewards = 57  
Iteration 231: Reward = 0, Total Rewards = 57  
Iteration 232: Reward = 0, Total Rewards = 57  
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Iteration 235: Reward = 0, Total Rewards = 58  
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Iteration 262: Reward = 1, Total Rewards = 70

Iteration 263: Reward = 0, Total Rewards = 70  
Iteration 264: Reward = 0, Total Rewards = 70  
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Iteration 268: Reward = 1, Total Rewards = 73  
Iteration 269: Reward = 0, Total Rewards = 73  
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Iteration 272: Reward = 0, Total Rewards = 74  
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Iteration 310: Reward = 0, Total Rewards = 92

Iteration 311: Reward = 0, Total Rewards = 92  
Iteration 312: Reward = 0, Total Rewards = 92  
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Iteration 316: Reward = 1, Total Rewards = 94  
Iteration 317: Reward = 0, Total Rewards = 94  
Iteration 318: Reward = 1, Total Rewards = 95  
Iteration 319: Reward = 0, Total Rewards = 95  
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Iteration 322: Reward = 1, Total Rewards = 96  
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Iteration 324: Reward = 1, Total Rewards = 98  
Iteration 325: Reward = 0, Total Rewards = 98  
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Iteration 329: Reward = 0, Total Rewards = 99  
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Iteration 343: Reward = 0, Total Rewards = 104  
Iteration 344: Reward = 1, Total Rewards = 105  
Iteration 345: Reward = 0, Total Rewards = 105  
Iteration 346: Reward = 0, Total Rewards = 105  
Iteration 347: Reward = 1, Total Rewards = 106  
Iteration 348: Reward = 1, Total Rewards = 107  
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Iteration 353: Reward = 0, Total Rewards = 111  
Iteration 354: Reward = 1, Total Rewards = 112  
Iteration 355: Reward = 1, Total Rewards = 113  
Iteration 356: Reward = 0, Total Rewards = 113  
Iteration 357: Reward = 1, Total Rewards = 114  
Iteration 358: Reward = 1, Total Rewards = 115



Iteration 359: Reward = 0, Total Rewards = 115  
Iteration 360: Reward = 0, Total Rewards = 115  
Iteration 361: Reward = 1, Total Rewards = 116  
Iteration 362: Reward = 0, Total Rewards = 116  
Iteration 363: Reward = 0, Total Rewards = 116  
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Iteration 365: Reward = 0, Total Rewards = 117  
Iteration 366: Reward = 0, Total Rewards = 117  
Iteration 367: Reward = 0, Total Rewards = 117  
Iteration 368: Reward = 0, Total Rewards = 117  
Iteration 369: Reward = 0, Total Rewards = 117  
Iteration 370: Reward = 1, Total Rewards = 118  
Iteration 371: Reward = 1, Total Rewards = 119  
Iteration 372: Reward = 1, Total Rewards = 120  
Iteration 373: Reward = 0, Total Rewards = 120  
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Iteration 382: Reward = 1, Total Rewards = 125  
Iteration 383: Reward = 0, Total Rewards = 125  
Iteration 384: Reward = 0, Total Rewards = 125  
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Iteration 387: Reward = 0, Total Rewards = 126  
Iteration 388: Reward = 0, Total Rewards = 126  
Iteration 389: Reward = 0, Total Rewards = 126  
Iteration 390: Reward = 0, Total Rewards = 126  
Iteration 391: Reward = 0, Total Rewards = 126  
Iteration 392: Reward = 1, Total Rewards = 127  
Iteration 393: Reward = 1, Total Rewards = 128  
Iteration 394: Reward = 0, Total Rewards = 128  
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Iteration 401: Reward = 0, Total Rewards = 129  
Iteration 402: Reward = 1, Total Rewards = 130  
Iteration 403: Reward = 0, Total Rewards = 130  
Iteration 404: Reward = 0, Total Rewards = 130  
Iteration 405: Reward = 1, Total Rewards = 131  
Iteration 406: Reward = 0, Total Rewards = 131

Iteration 407: Reward = 1, Total Rewards = 132  
Iteration 408: Reward = 1, Total Rewards = 133  
Iteration 409: Reward = 0, Total Rewards = 133  
Iteration 410: Reward = 1, Total Rewards = 134  
Iteration 411: Reward = 1, Total Rewards = 135  
Iteration 412: Reward = 0, Total Rewards = 135  
Iteration 413: Reward = 1, Total Rewards = 136  
Iteration 414: Reward = 0, Total Rewards = 136  
Iteration 415: Reward = 0, Total Rewards = 136  
Iteration 416: Reward = 0, Total Rewards = 136  
Iteration 417: Reward = 0, Total Rewards = 136  
Iteration 418: Reward = 0, Total Rewards = 136  
Iteration 419: Reward = 0, Total Rewards = 136  
Iteration 420: Reward = 0, Total Rewards = 136  
Iteration 421: Reward = 0, Total Rewards = 136  
Iteration 422: Reward = 0, Total Rewards = 136  
Iteration 423: Reward = 0, Total Rewards = 136  
Iteration 424: Reward = 0, Total Rewards = 136  
Iteration 425: Reward = 0, Total Rewards = 136  
Iteration 426: Reward = 1, Total Rewards = 137  
Iteration 427: Reward = 1, Total Rewards = 138  
Iteration 428: Reward = 1, Total Rewards = 139  
Iteration 429: Reward = 1, Total Rewards = 140  
Iteration 430: Reward = 0, Total Rewards = 140  
Iteration 431: Reward = 1, Total Rewards = 141  
Iteration 432: Reward = 0, Total Rewards = 141  
Iteration 433: Reward = 0, Total Rewards = 141  
Iteration 434: Reward = 0, Total Rewards = 141  
Iteration 435: Reward = 0, Total Rewards = 141  
Iteration 436: Reward = 0, Total Rewards = 141  
Iteration 437: Reward = 0, Total Rewards = 141  
Iteration 438: Reward = 0, Total Rewards = 141  
Iteration 439: Reward = 0, Total Rewards = 141  
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Iteration 441: Reward = 0, Total Rewards = 142  
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Iteration 443: Reward = 0, Total Rewards = 143  
Iteration 444: Reward = 0, Total Rewards = 143  
Iteration 445: Reward = 1, Total Rewards = 144  
Iteration 446: Reward = 1, Total Rewards = 145  
Iteration 447: Reward = 0, Total Rewards = 145  
Iteration 448: Reward = 0, Total Rewards = 145  
Iteration 449: Reward = 1, Total Rewards = 146  
Iteration 450: Reward = 1, Total Rewards = 147  
Iteration 451: Reward = 0, Total Rewards = 147  
Iteration 452: Reward = 1, Total Rewards = 148  
Iteration 453: Reward = 0, Total Rewards = 148  
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Iteration 919: Reward = 0, Total Rewards = 326  
Iteration 920: Reward = 1, Total Rewards = 327  
Iteration 921: Reward = 0, Total Rewards = 327  
Iteration 922: Reward = 0, Total Rewards = 327  
Iteration 923: Reward = 1, Total Rewards = 328  
Iteration 924: Reward = 0, Total Rewards = 328  
Iteration 925: Reward = 1, Total Rewards = 329  
Iteration 926: Reward = 0, Total Rewards = 329  
Iteration 927: Reward = 1, Total Rewards = 330  
Iteration 928: Reward = 0, Total Rewards = 330  
Iteration 929: Reward = 1, Total Rewards = 331  
Iteration 930: Reward = 1, Total Rewards = 332  
Iteration 931: Reward = 0, Total Rewards = 332  
Iteration 932: Reward = 1, Total Rewards = 333  
Iteration 933: Reward = 0, Total Rewards = 333  
Iteration 934: Reward = 0, Total Rewards = 333

Iteration 935: Reward = 0, Total Rewards = 333  
Iteration 936: Reward = 0, Total Rewards = 333  
Iteration 937: Reward = 1, Total Rewards = 334  
Iteration 938: Reward = 0, Total Rewards = 334  
Iteration 939: Reward = 0, Total Rewards = 334  
Iteration 940: Reward = 0, Total Rewards = 334  
Iteration 941: Reward = 0, Total Rewards = 334  
Iteration 942: Reward = 1, Total Rewards = 335  
Iteration 943: Reward = 0, Total Rewards = 335  
Iteration 944: Reward = 0, Total Rewards = 335  
Iteration 945: Reward = 1, Total Rewards = 336  
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Iteration 947: Reward = 0, Total Rewards = 337  
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Iteration 952: Reward = 0, Total Rewards = 337  
Iteration 953: Reward = 0, Total Rewards = 337  
Iteration 954: Reward = 0, Total Rewards = 337  
Iteration 955: Reward = 1, Total Rewards = 338  
Iteration 956: Reward = 1, Total Rewards = 339  
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Iteration 962: Reward = 1, Total Rewards = 342  
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Iteration 964: Reward = 0, Total Rewards = 343  
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Iteration 977: Reward = 1, Total Rewards = 347  
Iteration 978: Reward = 0, Total Rewards = 347  
Iteration 979: Reward = 0, Total Rewards = 347  
Iteration 980: Reward = 0, Total Rewards = 347  
Iteration 981: Reward = 0, Total Rewards = 347  
Iteration 982: Reward = 0, Total Rewards = 347

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Iteration 983: Reward = 1, Total Rewards = 348
Iteration 984: Reward = 1, Total Rewards = 349
Iteration 985: Reward = 0, Total Rewards = 349
Iteration 986: Reward = 0, Total Rewards = 349
Iteration 987: Reward = 1, Total Rewards = 350
Iteration 988: Reward = 1, Total Rewards = 351
Iteration 989: Reward = 1, Total Rewards = 352
Iteration 990: Reward = 1, Total Rewards = 353
Iteration 991: Reward = 1, Total Rewards = 354
Iteration 992: Reward = 0, Total Rewards = 354
Iteration 993: Reward = 1, Total Rewards = 355
Iteration 994: Reward = 1, Total Rewards = 356
Iteration 995: Reward = 0, Total Rewards = 356
Iteration 996: Reward = 0, Total Rewards = 356
Iteration 997: Reward = 1, Total Rewards = 357
Iteration 998: Reward = 0, Total Rewards = 357
Iteration 999: Reward = 1, Total Rewards = 358
Iteration 1000: Reward = 0, Total Rewards = 358
Total Rewards from Epsilon-Greedy Policy: 358

```

## 12 Using UCB (0.5M)

Print all the iterations with random policy selected for the given Ad. (Mandatory)

```

[52]: # run the environment with an agent that is guided by a UCB
#-----write your code below this line-----

def ucb_policy(env, iterations):
    """
    Implements the Upper Confidence Bound (UCB) policy for selecting arms (ads)
    in the environment.

    Parameters:
    - env (CTREnvironment): The environment object containing ads and their
    probabilities.
    - iterations (int): Number of iterations (rounds) to run the policy.

    Returns:
    - list: List of total rewards accumulated after each iteration.
    """
    total_rewards = [] # List to store cumulative rewards after each iteration

    for t in range(1, iterations + 1):
        ucb_values = env.values + np.sqrt(2 * np.log(t) / (env.counts + 1)) #
        Calculate UCB values

        arm = np.argmax(ucb_values) # Choose the arm with the highest UCB value

```

```

    reward = env.select_arm(arm) # Get reward for selecting the arm

    total_rewards.append(env.total_reward) # Append total reward after
    ↪each iteration
    print(f"Iteration {t}: Reward = {reward}, Total Rewards =
    ↪{total_rewards[-1]}") # Print iteration details

    return total_rewards # Return list of total rewards accumulated

env.reset() # Reset the environment
ucb_rewards = ucb_policy(env, 1000) # Execute UCB policy for 1000 iterations
print("Total Rewards from UCB Policy:", ucb_rewards[-1]) # Print total rewards
    ↪accumulated

```

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Iteration 1: Reward = 0, Total Rewards = 0
Iteration 2: Reward = 0, Total Rewards = 0
Iteration 3: Reward = 0, Total Rewards = 0
Iteration 4: Reward = 0, Total Rewards = 0
Iteration 5: Reward = 1, Total Rewards = 1
Iteration 6: Reward = 1, Total Rewards = 2
Iteration 7: Reward = 1, Total Rewards = 3
Iteration 8: Reward = 1, Total Rewards = 4
Iteration 9: Reward = 0, Total Rewards = 4
Iteration 10: Reward = 0, Total Rewards = 4
Iteration 11: Reward = 0, Total Rewards = 4
Iteration 12: Reward = 0, Total Rewards = 4
Iteration 13: Reward = 0, Total Rewards = 4
Iteration 14: Reward = 0, Total Rewards = 4
Iteration 15: Reward = 0, Total Rewards = 4
Iteration 16: Reward = 0, Total Rewards = 4
Iteration 17: Reward = 0, Total Rewards = 4
Iteration 18: Reward = 0, Total Rewards = 4
Iteration 19: Reward = 0, Total Rewards = 4
Iteration 20: Reward = 0, Total Rewards = 4
Iteration 21: Reward = 1, Total Rewards = 5
Iteration 22: Reward = 0, Total Rewards = 5
Iteration 23: Reward = 1, Total Rewards = 6
Iteration 24: Reward = 0, Total Rewards = 6
Iteration 25: Reward = 0, Total Rewards = 6
Iteration 26: Reward = 0, Total Rewards = 6
Iteration 27: Reward = 0, Total Rewards = 6
Iteration 28: Reward = 0, Total Rewards = 6
Iteration 29: Reward = 1, Total Rewards = 7
Iteration 30: Reward = 1, Total Rewards = 8
Iteration 31: Reward = 0, Total Rewards = 8
Iteration 32: Reward = 0, Total Rewards = 8

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Iteration 33: Reward = 0, Total Rewards = 8  
Iteration 34: Reward = 1, Total Rewards = 9  
Iteration 35: Reward = 0, Total Rewards = 9  
Iteration 36: Reward = 1, Total Rewards = 10  
Iteration 37: Reward = 0, Total Rewards = 10  
Iteration 38: Reward = 0, Total Rewards = 10  
Iteration 39: Reward = 1, Total Rewards = 11  
Iteration 40: Reward = 0, Total Rewards = 11  
Iteration 41: Reward = 0, Total Rewards = 11  
Iteration 42: Reward = 0, Total Rewards = 11  
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Iteration 72: Reward = 0, Total Rewards = 14  
Iteration 73: Reward = 1, Total Rewards = 15  
Iteration 74: Reward = 1, Total Rewards = 16  
Iteration 75: Reward = 1, Total Rewards = 17  
Iteration 76: Reward = 0, Total Rewards = 17  
Iteration 77: Reward = 0, Total Rewards = 17  
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Iteration 80: Reward = 0, Total Rewards = 17



Iteration 81: Reward = 0, Total Rewards = 17  
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Iteration 84: Reward = 0, Total Rewards = 17  
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Iteration 90: Reward = 1, Total Rewards = 20  
Iteration 91: Reward = 1, Total Rewards = 21  
Iteration 92: Reward = 0, Total Rewards = 21  
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Iteration 95: Reward = 0, Total Rewards = 22  
Iteration 96: Reward = 0, Total Rewards = 22  
Iteration 97: Reward = 0, Total Rewards = 22  
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Iteration 110: Reward = 0, Total Rewards = 26  
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Iteration 116: Reward = 0, Total Rewards = 29  
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Iteration 157: Reward = 0, Total Rewards = 39  
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Iteration 173: Reward = 0, Total Rewards = 40  
Iteration 174: Reward = 0, Total Rewards = 40  
Iteration 175: Reward = 0, Total Rewards = 40  
Iteration 176: Reward = 0, Total Rewards = 40

[illegible]

Iteration 225: Reward = 0, Total Rewards = 43  
Iteration 226: Reward = 1, Total Rewards = 44  
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Iteration 230: Reward = 0, Total Rewards = 46  
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Iteration 272: Reward = 0, Total Rewards = 57

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Iteration 359: Reward = 0, Total Rewards = 73  
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Iteration 368: Reward = 0, Total Rewards = 75

Iteration 369: Reward = 0, Total Rewards = 75  
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Iteration 990: Reward = 1, Total Rewards = 218  
Iteration 991: Reward = 1, Total Rewards = 219  
Iteration 992: Reward = 1, Total Rewards = 220

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Iteration 993: Reward = 1, Total Rewards = 221
Iteration 994: Reward = 0, Total Rewards = 221
Iteration 995: Reward = 1, Total Rewards = 222
Iteration 996: Reward = 0, Total Rewards = 222
Iteration 997: Reward = 0, Total Rewards = 222
Iteration 998: Reward = 0, Total Rewards = 222
Iteration 999: Reward = 0, Total Rewards = 222
Iteration 1000: Reward = 1, Total Rewards = 223
Total Rewards from UCB Policy: 223

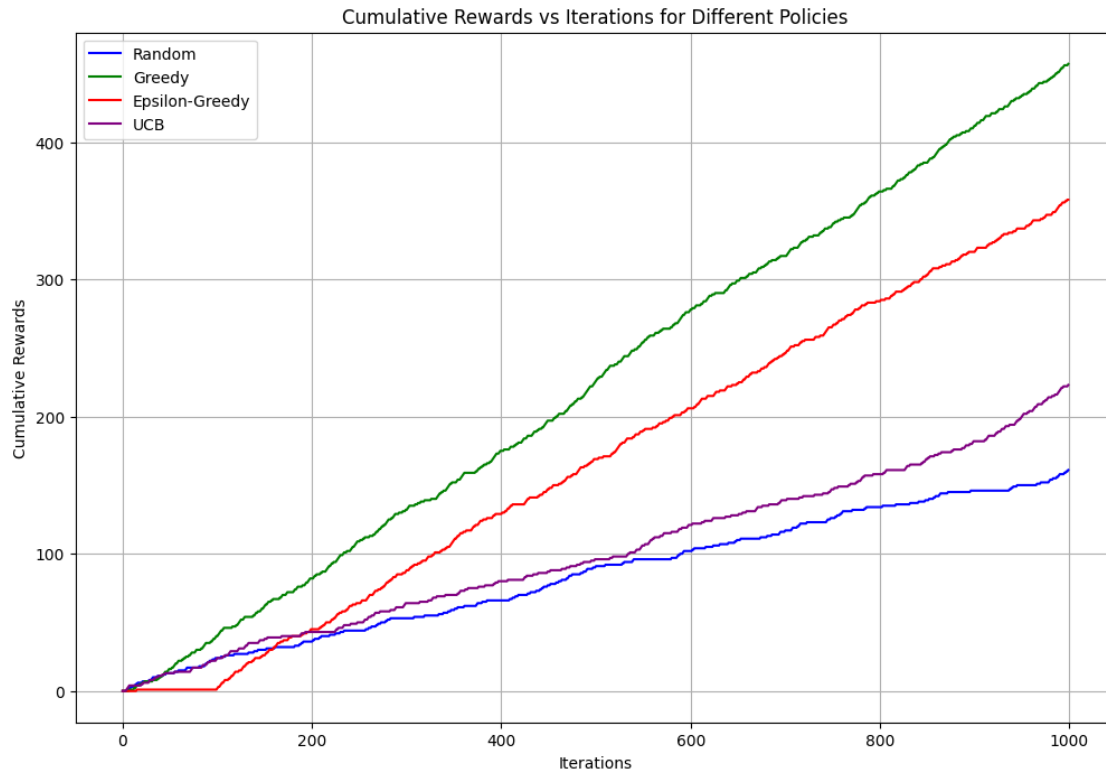
```

```

[53]: #-----write your code below this line-----
def total_rewards_graph(total_rewards_list, titles):
    policies = ['Random', 'Greedy', 'Epsilon-Greedy', 'UCB']
    colors = ['blue', 'green', 'red', 'purple']
    plt.figure(figsize=(12, 8))
    for i, total_rewards in enumerate(total_rewards_list):
        plt.plot(total_rewards, label=policies[i], color=colors[i])
    plt.title(titles)
    plt.xlabel('Iterations')
    plt.ylabel('Cumulative Rewards')
    plt.legend()
    plt.grid(True)
    plt.show()

total_rewards_list = [random_rewards, greedy_rewards, epsilon_greedy_rewards,
    ↪ucb_rewards]
total_rewards_graph(total_rewards_list, "Cumulative Rewards vs Iterations for
    ↪Different Policies")

```



### 13 Changing Exploration Percentage (1M)

- How does changing the exploration percentage (EXPLORE\_PERCENTAGE) affect the performance of the algorithm? Test with different values (e.g. 0.15 and 0.2) and discuss the results.

```
[54]: def exploration_percentage_change(env, explore_percentage, iterations):
        rewards = epsilon_greedy_policy(env, iterations, epsilon=explore_percentage)
        return rewards

# Test different exploration percentages
env.reset()
fifteen_percent = exploration_percentage_change(env, 0.15, 1000)
env.reset()
twenty_percent = exploration_percentage_change(env, 0.20, 1000)

print("Rewards with 15% exploration:", fifteen_percent[-1])
print("Rewards with 20% exploration:", twenty_percent[-1])

total_rewards_array = [fifteen_percent, twenty_percent]
total_rewards_graph(total_rewards_array, "Cumulative Rewards vs Iterations for_
↳ Different Exploration Percentages")
```

Iteration 1: Reward = 0, Total Rewards = 0  
Iteration 2: Reward = 0, Total Rewards = 0  
Iteration 3: Reward = 0, Total Rewards = 0  
Iteration 4: Reward = 0, Total Rewards = 0  
Iteration 5: Reward = 0, Total Rewards = 0  
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[illegible]

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Iteration 776: Reward = 0, Total Rewards = 341

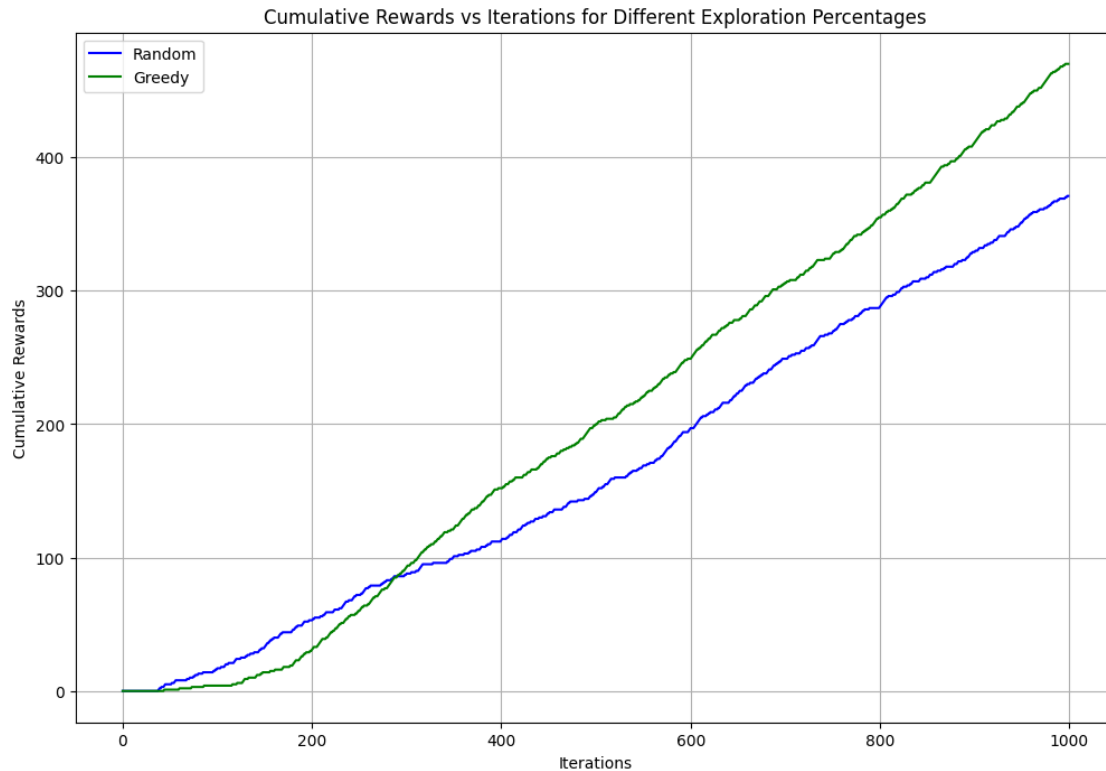
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Iteration 799: Reward = 0, Total Rewards = 354  
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Iteration 801: Reward = 0, Total Rewards = 355  
Iteration 802: Reward = 0, Total Rewards = 355  
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Iteration 804: Reward = 1, Total Rewards = 357  
Iteration 805: Reward = 0, Total Rewards = 357  
Iteration 806: Reward = 0, Total Rewards = 357  
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Iteration 829: Reward = 1, Total Rewards = 372  
Iteration 830: Reward = 0, Total Rewards = 372  
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Iteration 998: Reward = 0, Total Rewards = 470  
Iteration 999: Reward = 0, Total Rewards = 470  
Iteration 1000: Reward = 0, Total Rewards = 470  
Rewards with 15% exploration: 371  
Rewards with 20% exploration: 470



## 14 Conclusion (0.5M)

Conclude your assignment in 250 words by discussing the best approach for maximizing the CTR using random, greedy, epsilon-greedy and UCB.

## Conclusion Based on the above results, using the Greedy policy (total rewards 457) and Epsilon-Greedy approach (total rewards 358) allowed us to achieve maximum rewards. Specifically, we obtained 223 rewards with the UCB policy and 161 rewards with the Random policy.

And for epsilon greedy policy with 20% exploration we could maximize the rewards