In [214…
```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
```

In [215…
```
data_path = "data.xlsx"
data = pd.read_excel(data_path)
data.head()
```

Out[215]:

| | user_id | test | converted | tot_impr | mode_impr_day | mode_impr_hour |
|---|---|---|---|---|---|---|
| **0** | 1069124 | 1 | 0 | 130 | 1 | 20 |
| **1** | 1119715 | 1 | 0 | 93 | 2 | 22 |
| **2** | 1144181 | 1 | 0 | 21 | 2 | 18 |
| **3** | 1435133 | 1 | 0 | 355 | 2 | 10 |
| **4** | 1015700 | 1 | 0 | 276 | 5 | 14 |

In [216…
```
data.describe()
```

Out[216]:

| | user_id | test | converted | tot_impr | mode_impr_day | mode_in |
|---|---|---|---|---|---|---|
| **count** | 5.881010e+05 | 588101.000000 | 588101.000000 | 588101.000000 | 588101.000000 | 58810 |
| **mean** | 1.310692e+06 | 0.960000 | 0.025239 | 24.820876 | 4.025533 | 1 |
| **std** | 2.022260e+05 | 0.195959 | 0.156850 | 43.715181 | 2.004019 | |
| **min** | 9.000000e+05 | 0.000000 | 0.000000 | 1.000000 | 1.000000 | |
| **25%** | 1.143190e+06 | 1.000000 | 0.000000 | 4.000000 | 2.000000 | 1 |
| **50%** | 1.313725e+06 | 1.000000 | 0.000000 | 13.000000 | 4.000000 | 1 |
| **75%** | 1.484088e+06 | 1.000000 | 0.000000 | 27.000000 | 6.000000 | 1 |
| **max** | 1.654483e+06 | 1.000000 | 1.000000 | 2065.000000 | 7.000000 | 2 |

# Q1.

In [239…
```
total_num_users = data.shape[0]
total_conversions = data[data['converted'] == 1].shape[0]
test_group = data[data['test'] == 1]
control_group = data[data['test'] == 0]
test_group_count, control_group_count = test_group.shape[0],  control_group.sh
converted_from_test_grp = test_group[test_group['converted'] == 1]
converted_from_test_grp_count = converted_from_test_grp.shape[0]
converted_from_control_grp = control_group[control_group['converted'] == 1]
converted_from_control_grp_count = converted_from_control_grp.shape[0]
print(f'Total number of identified users: {total_num_users}')
print(f'Total number of converted users: {total_conversions}\n')
print(f'Total number of users exposed to advertising (Test Group): {test_group_
print(f'Total number of users not exposed to advertising (Control Group): {con
print(f'Number of Users that bought the handbag in Test Group: {converted_from_
print(f'Number of Users that bought the handbag in Control Group: {converted_f
```

```
percent_conv_rate_test = converted_from_test_grp_count / test_group_count
percent_conv_rate_control = converted_from_control_grp_count / control_group_c
print(f'Percentage conversion rate of users (Test Group): {round(percent_conv_
print(f'Percentage conversion rate of users (Control Group): {round(percent_co

print(f'Percentage of users converted because of the ad campaign: {round((perc
```

```
Total number of identified users: 588101
Total number of converted users: 14843

Total number of users exposed to advertising (Test Group): 564577
Total number of users not exposed to advertising (Control Group): 23524

Number of Users that bought the handbag in Test Group: 14423
Number of Users that bought the handbag in Control Group: 420

Percentage conversion rate of users (Test Group): 2.5547%
Percentage conversion rate of users (Control Group): 1.7854%

Percentage of users converted because of the ad campaign: 0.7692%
```

# Discussion Q1 -

## Was the advertising campaign effective? Did additional consumers convert as a result of the ad campaign?

# Answer 1 -

Yes, the campaign was effective. In the test group, a conversion rate of 2.5547% was witnessed which is much higher than 1.7854%, the conversion rate of the control group. It was also ensured that the size of the control group is sufficient to detect lift. Thus, with 4% control group, we can safely conclude that the results are valid and demonstrate the effectiveness of the ad campaign.

# Q2 (a)

In [218…

```
num_users_converted_in_test_group_if_no_ad = percent_conv_rate_control * test_
num_users_converted_in_test_group_with_ad = converted_from_test_grp_count
net__additional_num_user_converted = num_users_converted_in_test_group_with_ad
converting_user_worth = 40
print(f"Number of users converted in test group if no ad: {round(num_users_con
print(f"Number of users converted in test group with ad: {num_users_converted_
print(f"Net additional numbber of users converted in test group due to ad: {ro
print(f"Converting user worth: ${converting_user_worth}")
total_profit = net__additional_num_user_converted * converting_user_worth
print(f"Total profit: ${round(total_profit, 4)}")
```

```
Number of users converted in test group if no ad: 10080.0179
Number of users converted in test group with ad: 14423
Net additional numbber of users converted in test group due to ad: 4342.9821
Converting user worth: $40
Total profit: $173719.2858
```

## Answer 2 (a).

The control group was not sent the ads.

The number of users in the Test group that TaskaBella would have converted if there were no ads sent would be: the conversion rate without ads times the number of users in the Test group - which is approximately ~10,080. Let this be n number of users. n = 10080.

The additional users that TaskaBella was able to convert due to the ad campaign is equal to the number of user converted in Test Group, which is 14423. Let this be m number of users. m = 14423.

The net additional number of users that TaskaBella was able to convert due to ad campaign is n - m = 14423 - 10080 = approx. 4342.

With each converted user worth $40, and excluding advertising costs, TaskaBella made $173719.2858 more money by running the campaign.

# Q2 (b)

In [307…
```
tot_impr = data['tot_impr'].sum()
avg_cpm = 9
total_ad_cost = avg_cpm * (tot_impr / 1000)
print(f"Total number of impressions: {tot_impr}")
print(f"Average CPM: ${avg_cpm}")
print(f"Total ad cost: ${total_ad_cost}")
print(f"Ad cost per user reached: ${round(total_ad_cost / total_num_users, 4)}"
print(f"Ad cost per conversion: ${round(total_ad_cost / net__additional_num_us
```

```
Total number of impressions: 14597182
Average CPM: $9
Total ad cost: $131374.638
Ad cost per user reached: $0.2234
Ad cost per conversion: $30.2499
```

## Answer 2 (b).

The total number of impressions were 14,597,182. The costs of impressions per thousand (CPM) was $9.

The total advertisement cost would thus be (14,597,182 / 1000) * 9 = $131374.638. This was the cost of the campaign.

# Q2 (c)

In [220…
```
net_profit = total_profit - total_ad_cost
total_ROI = (net_profit / total_ad_cost) * 100
```

```
print(f"Additional Money made due to ads: ${round(total_profit, 4)}")
print(f"Total cost of campaign: ${total_ad_cost}\n")
print(f"Net Profit: $ {round(net_profit, 4)}")
print(f"Total ROI: {round(total_ROI, 4)}%")
```

```
Additional Money made due to ads: $173719.2858
Total cost of campaign: $131374.638

Net Profit: $ 42344.6478
Total ROI: 32.232%
```

## Answer 2 (c).

The additional money made due to the ads is $173719.2858.

The total advertisement cost is $131374.638.

Thus, the net profit of the campaign is (total profit - cost) = $42344.6478.

The return on investment (ROI) of the campaign is 32.232%.

Yes, the campaign was profitable as ROI was 32.232%.

# Q2 (d)

In [221…

```
total_conversion_in_control_group_if_it_was_test = control_group_count * percer
curr_converion_control_group = converted_from_control_grp_count
additional_conversion_if_no_control_group = total_conversion_in_control_group_
opportunity_cost_if_no_control_group = additional_conversion_if_no_control_grou
print(f"Total number of conversions in control group with test group conversio
print(f"Total number of conversions in control group without ads: {curr_conver
print(f"Additional conversions if no control group (one test group with all us
print(f"Opportunity cost (no control group): ${round(opportunity_cost_if_no_co
```

```
Total number of conversions in control group with test group conversion rate:
600.9573
Total number of conversions in control group without ads: 420
Additional conversions if no control group (one test group with all users): 18
0.9573

Opportunity cost (no control group): $7238.2908
```

### Let us explore different control group sizes and the changes in opportunity costs

You can change the value of the variable below to see the different effects of having different control group sizes.

In [222…

```
# Set the control group size in percentage, e.g. 2 for 2% of user population
ctrl_group_size = 2
```

In [223…

```
def calc_opp_cost(control_group_size, is_print):
    new_control_group = (control_group_size / 100) * total_num_users
```

```
    new_test_group = ((100 - control_group_size) / 100) * total_num_users

    new_num_conv_ctrl_grp = new_control_group * percent_conv_rate_control
    new_num_conv_test_grp = new_test_group * percent_conv_rate_test
    if is_print:
        print(f"If we change the size of the control group to {control_group_s
        print(f"The number of people in the control group would be {control_gr
        print(f"The number of people in the test group would be {100 - control_
        print(f"The number of conversions in the control group would be: {roun
        print(f"The number of conversions in the test group would be: {round(n

    if control_group_size < 4:
        new_user_in_test_grp = new_test_group - test_group_count
        users_converted_if_in_ctrl_grp = new_user_in_test_grp * percent_conv_r
        users_converted_now_in_test_grp = new_user_in_test_grp * percent_conv_
        additional_conversions_in_test_grp = users_converted_now_in_test_grp -

        new_opp_cost = additional_conversions_in_test_grp * converting_user_wo
        if is_print:
            print(f"\nWe had {test_group_count} users in the test group earlie
            print(f"Now, we have {new_test_group} users in the test group if o
            print(f"Out of the {control_group_size}% user population that move
            print(f"{round(users_converted_if_in_ctrl_grp, 4)} users would hav
            print(f"However, now {round(users_converted_now_in_test_grp, 4)} c
            print(f"Additional users converted is {round(additional_conversion
            print(f"New opportunity cost is ${round(new_opp_cost, 4)}.\n")
        return new_opp_cost

calc_opp_cost(ctrl_group_size, True)
ctrl_grp_sizes = [0, 1, 2, 3]
for ctrl_size in ctrl_grp_sizes:
    opp_cost = calc_opp_cost(ctrl_size, False)
    print(f"Control Group Size: {ctrl_size} - Opportunity Cost: ${round(opp_co
```

```
If we change the size of the control group to 2% of the user population. Then,
the following would happen:

The number of people in the control group would be 2% of the user population:
11762.02
The number of people in the test group would be 98% of the user population: 57
6338.98

The number of conversions in the control group would be: 210.0004
The number of conversions in the test group would be: 14723.4781

We had 564577 users in the test group earlier.
Now, we have 576338.98 users in the test group if only 2% of the user populati
on in control group instead of 4%.
Out of the 2% user population that moved from control group to test group:
209.9996 users would have converted if they were in the control group.
However, now 300.4781 convert in the test group due to the higher conversion r
ate.
Additional users converted is 90.4785.

New opportunity cost is $3619.1392.

Control Group Size: 0 - Opportunity Cost: $7238.2908
Control Group Size: 1 - Opportunity Cost: $5428.715
Control Group Size: 2 - Opportunity Cost: $3619.1392
Control Group Size: 3 - Opportunity Cost: $1809.5635
```

# Answer 2 (d).

Assuming that there was no control group, we would see the conversion rate of the test group for the current control group as well.

The total number of conversions in the control group without without specific ads is 420. If there was no control group, for the same 4% of the population we currently have in the control group, we would see the conversion rate of test group. This would make the total number of conversions for that 4% population, the current control group to be approximately 600.

The additional conversions we would have if there was no control group are approximately 180.

Thus, the opportunity cost (no control group) would be $7238.2908

Similarly, after analysing differen control group sizes, we found the following opportunity costs:

Control group population size and corresponsing opportunity costs:

0% - $ 7238.2908

1% - $ 5428.715

2% - $ 3619.1392

3% - $ 1809.5635

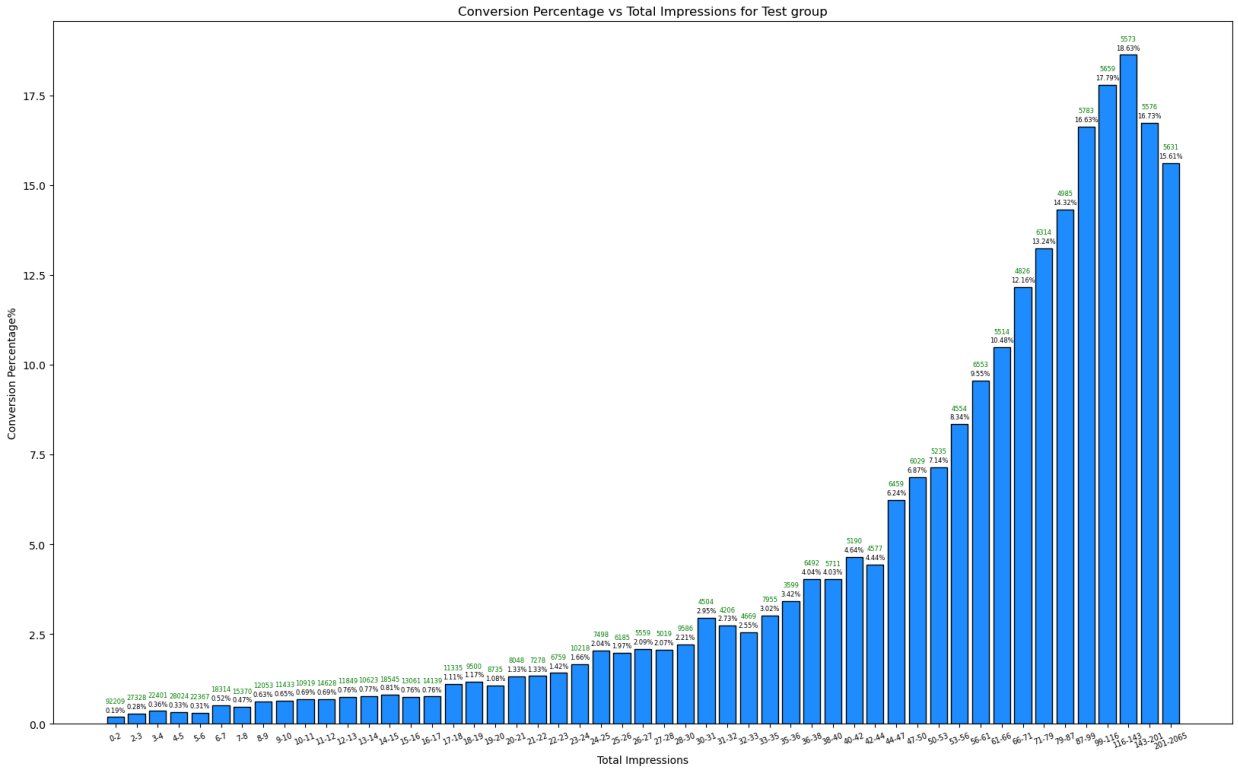
# Q3 (a)

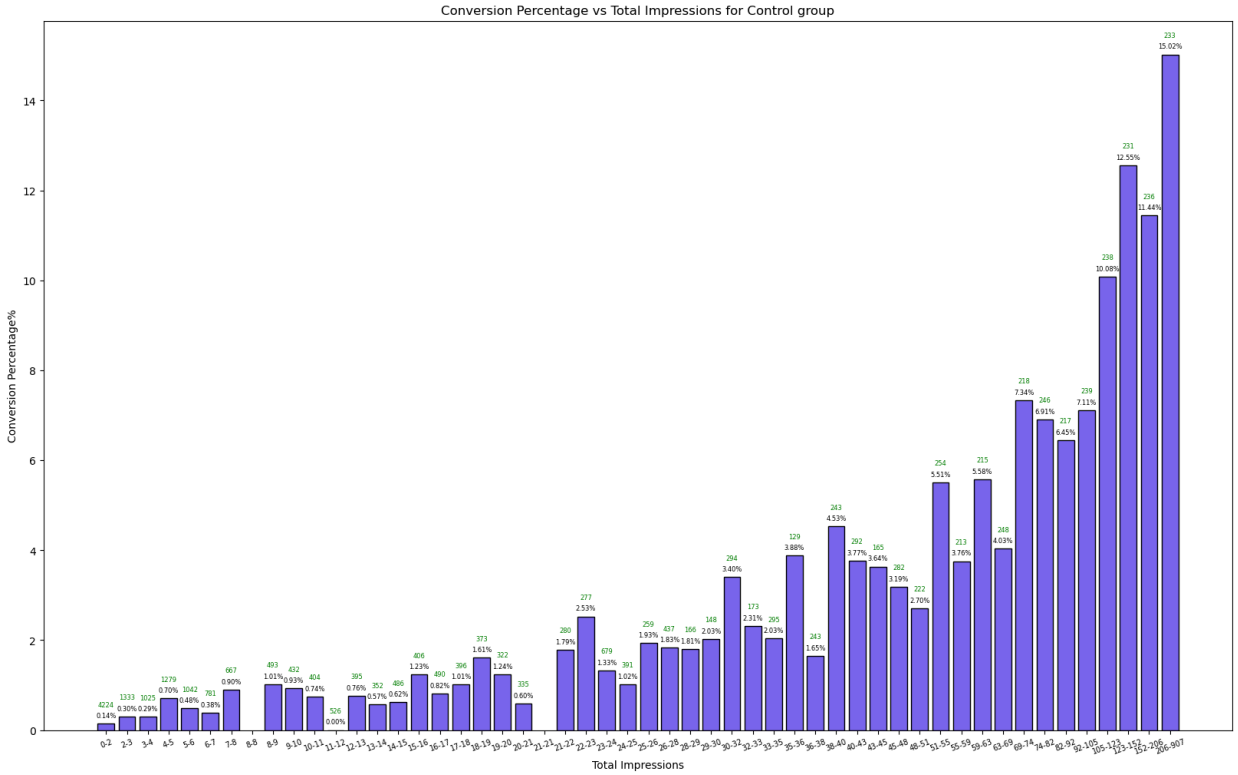
In [303…

```
def plot_graph(group_conv_rate, group_edges, color, case, num_people_each_grou
    plt.figure(figsize=(20, 12))
    x_labels_compute = []
    for i in range(len(group_edges)):
        x_labels_compute.append(str(group_edges[i][0]) + "-" + str(group_edges

    bars = plt.bar(x_labels_compute, group_conv_rate, color = color, edgecolor

    for bar, rate, people in zip(bars, group_conv_rate, num_people_each_group)
        if not (np.isnan(rate) or np.isinf(rate)):
            plt.text(bar.get_x() + bar.get_width() / 2, bar.get_height() + 0.1
            plt.text(bar.get_x() + bar.get_width() / 2, bar.get_height() + 0.3

    plt.xticks(rotation = 20, fontsize = 7)
    plt.xlabel("Total Impressions")
    plt.ylabel("Conversion Percentage%")
    plt.title("Conversion Percentage vs Total Impressions for " + str(case) + '
    plt.show()
```

In [304…
```
def compute_graphs(dataframe, color, case):
    curr_df = dataframe.copy()
    curr_df["groups"] = pd.qcut(curr_df["tot_impr"], q = 100, duplicates = "dr
    group_data = curr_df.groupby("groups")
    group_conversion_rate = (group_data["converted"].sum() / group_data["conve

    num_people_each_group = group_data.size()
    #print(num_people_each_group)

    group_edges = []
    for curr_group in curr_df["groups"].cat.categories:
        leftval = 0
        if curr_group.left >= 0:
            leftval = int(curr_group.left)
        group_edges.append((leftval, int(curr_group.right)))

    plot_graph(group_conversion_rate, group_edges, color, case, num_people_eacl
```

In [305…
```
compute_graphs(test_group, "dodgerblue", "Test")
compute_graphs(control_group, "mediumslateblue", "Control")
```






In [262…
```
count = (data['tot_impr'] > 200).sum()
print("Number of rows with greater than 200 impressions:", count)
print(f"Percentage of rows with total impressions greater than 200: {round(cou
```

```
Number of rows with greater than 200 impressions: 5952
Percentage of rows with total impressions greater than 200: 0.0101%
```

# Q3 (b) What do you infer from the charts? In what region is advertising most effective?

## For the test group:

The advertising is most effective when the number of impressions are between 116-143. The advertising is least effective when the number of impressions are between 0-2.

However, in general we can infer from the trend that the region 87-201 is where the conversion rate is the highest.

Thus, we believe that user conversion depends a lot on the number of impressions they have seen. It's extremely important to make sure that the number of impressions are in the adequate range to ensure that the advertisment campaign is succesful and users are converting.

People who saw 87 to 201 number of impressions were persuaded the most to make a purchase but the people who saw lesser number of impressions were not that persuaded enough to make the purchase. Lower number of impressions (< 30) end up being very ineffective for adverstiment success perspectives. If impressions are less than 17, conversion rate is < 1%.

Since conversion rate is the highest in the range when impressions are between 87 and 201, advertising is most effective for that number of impressions.

### For the control group:

The PSA notices were most effective when they were greater than 105.

For lower number of PSA notices, we can easily decipher that conversion rates are very low. Also, it's interesting to notice that conversion rates increase with the increase in PSA announcements but still remain a lot lower than ad conversion rates.

We can say that the PSA notice effectiveness was the highest when numnber of impressions is greater than 105. In general, we can infer that conversion rates increase with increase in impressions.

# Q3 (c) What do the figures imply for future campaigns?

## For the test group:

Send between 87 to 201 impressions to the consumers in-order to make sure that the advertisment campaign is run succesfully. Sending less than 87 impressions would lead to lower conversion rates and therefore lower profits. Furthermore, sending more than 201 impression doesn't really help that much. Therefore, to ensure that the ad campaign is run succesfully it's advisable to keep the impressions per user betweeen 87 and 201. This will ensure that profits are maximised and ROI is the maximum. To be very sprcific, the best results are between impressions 116 and 143.

## For the control group:

For the control group, it's recommended to send greater than 105 impressions in-order to maximize return. In order to get insights into the effectiveness of the campaign, it would be best to send impressions to users in the control group exactly like they are sent to users in the test group. This way, we can model the true impact of impressions for both the groups and understand the effectiveness of the ad campaign.

# Q4. (a)

In [228…

```
def plot_graph_Q4(x_vals, conv_rate, case, color, title):
    rates = []
    plt.figure(figsize=(10, 6))
    bars = plt.bar(x_vals, conv_rate, edgecolor = "black", color = color)
    for bar, rate in zip(bars, conv_rate):
```

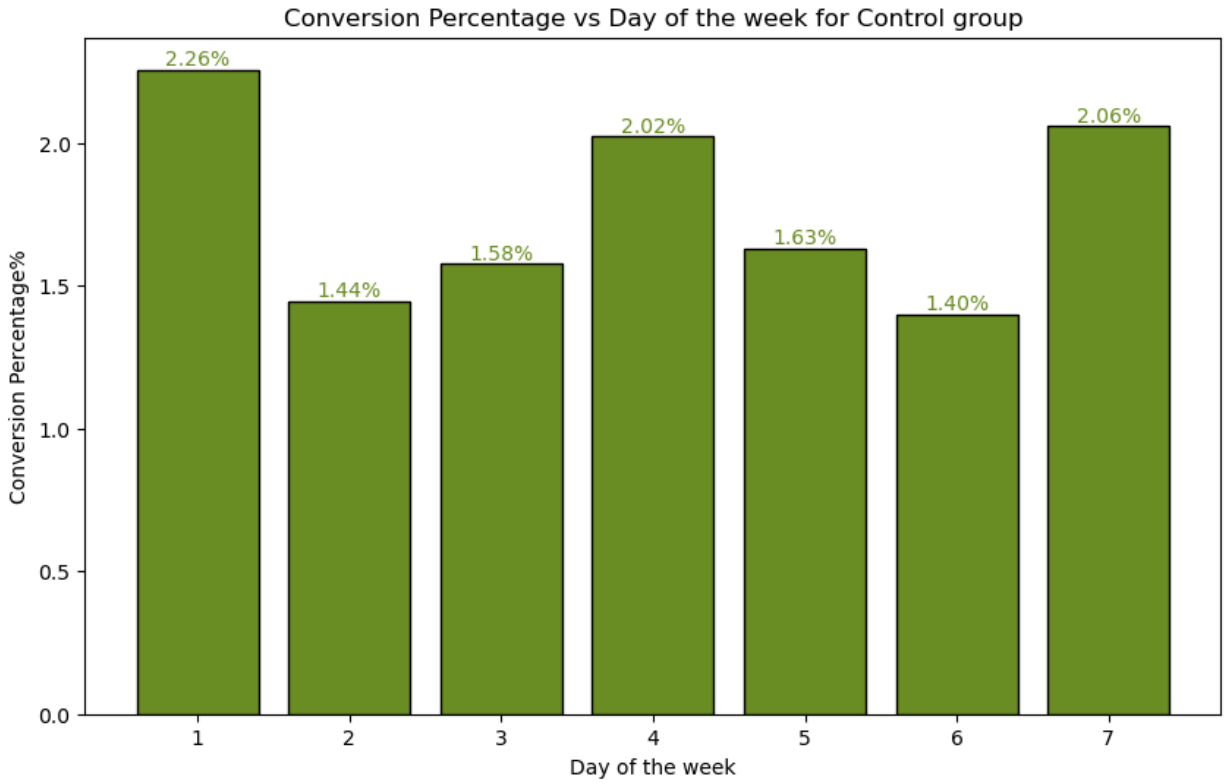
```
        plt.text(bar.get_x() + bar.get_width() / 2, bar.get_height() + 0.0003,
        rates.append(rate)
    plt.xlabel(f"{title}")
    plt.ylabel("Conversion Percentage%")
    plt.title("Conversion Percentage vs " + title + " for " + case + " group")
    plt.show()
    return rates
```

In [229…

```
def compute_graphs_Q4(dataframe, col_name, case, color, title):
    curr_df = dataframe.copy()
    group_conversion_rate = (curr_df.groupby(col_name)["converted"].sum() / cu
    rates = plot_graph_Q4(group_conversion_rate.index, group_conversion_rate.va
    return rates
```

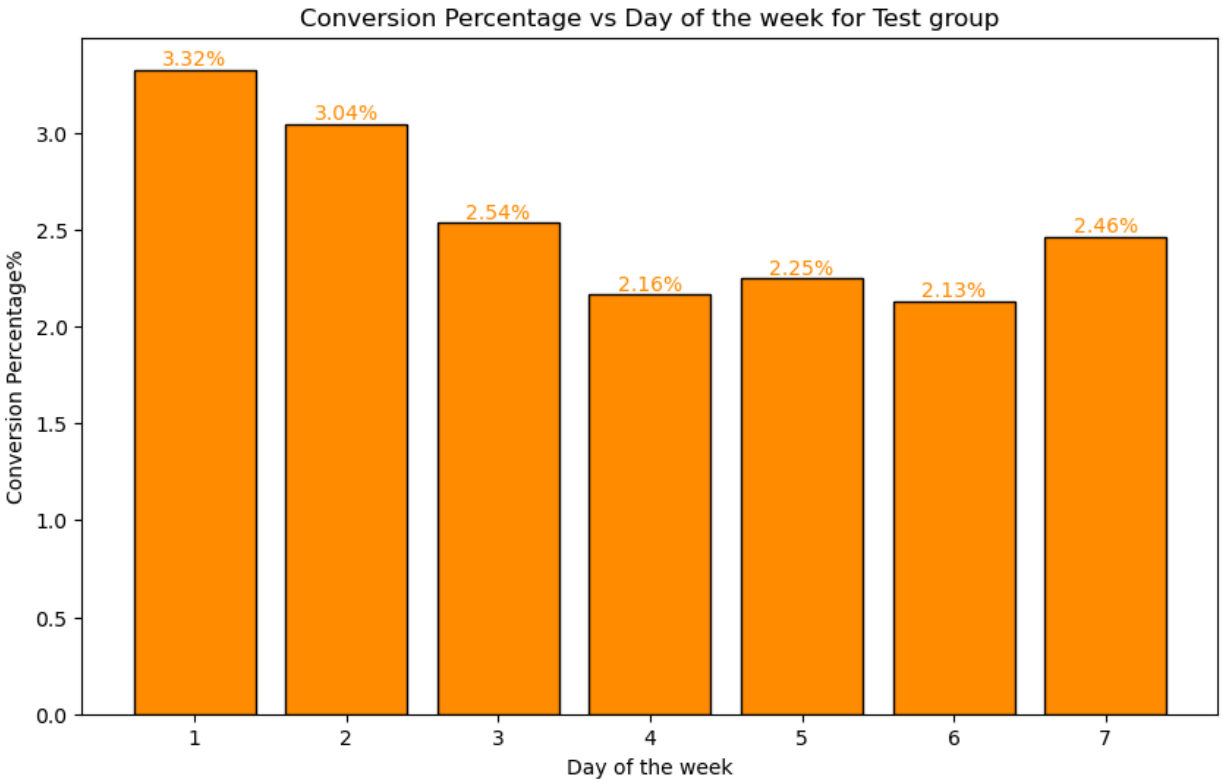
In [230…

```
rates_days_ctrl = compute_graphs_Q4(control_group, "mode_impr_day", "Control",
```




In [231…

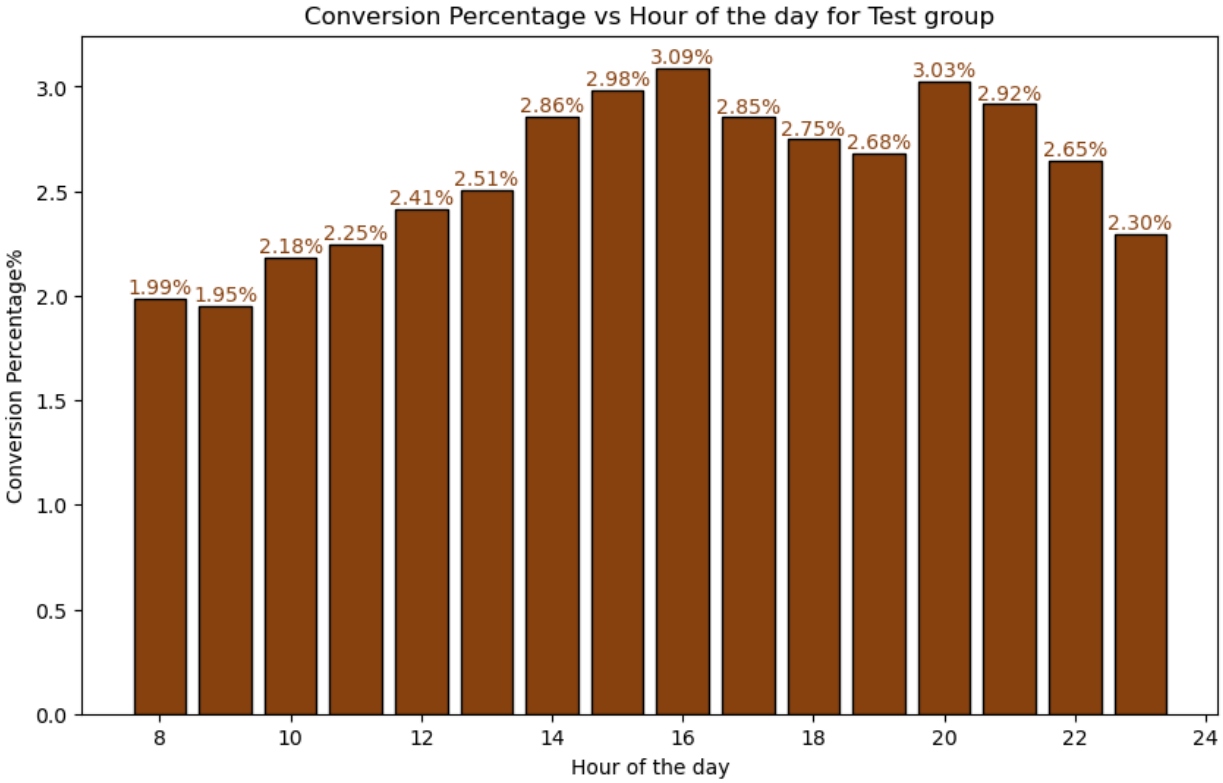
```
rates_days_test = compute_graphs_Q4(test_group, "mode_impr_day", "Test", "dark
```



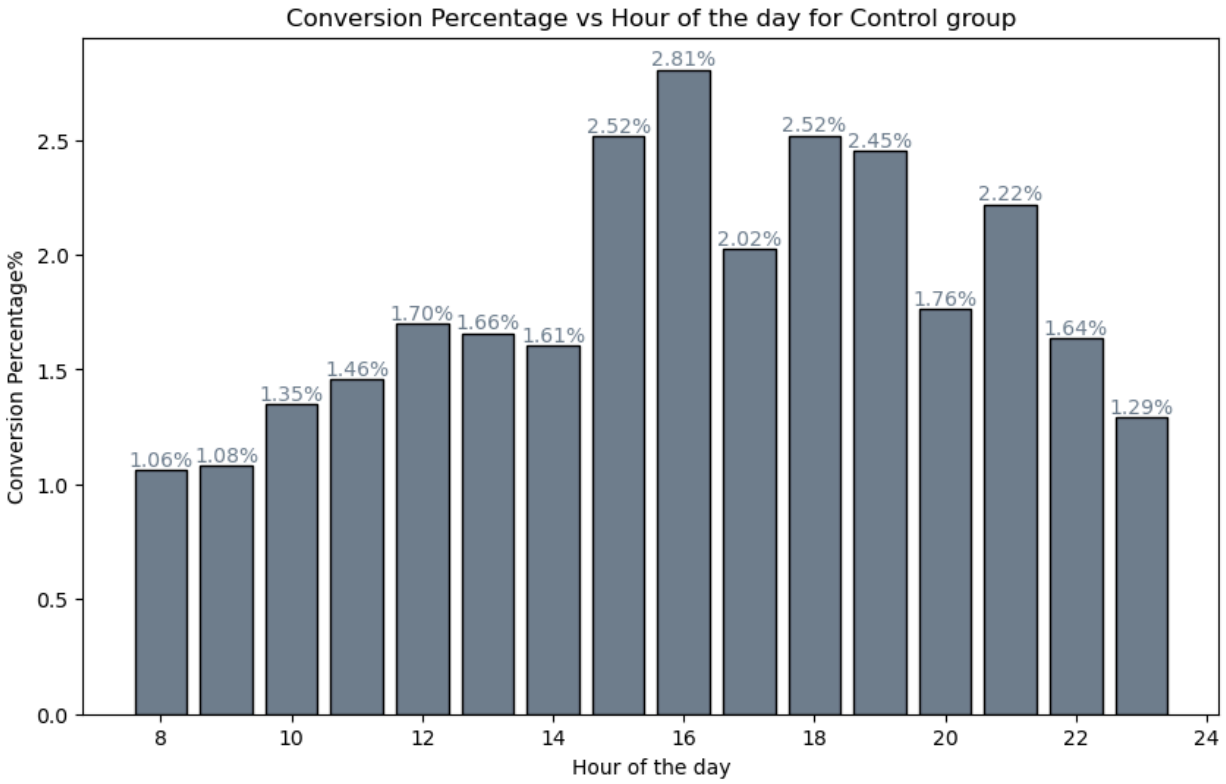

# Q4. (b)

In [232…

```
filter_hours = test_group[test_group["mode_impr_hour"] >= 8]
rates_hours_test = compute_graphs_Q4(filter_hours, "mode_impr_hour", "Test", "
```



In [233…
```
filter_hours_control = control_group[control_group["mode_impr_hour"] >= 8]
rates_hours_ctrl = compute_graphs_Q4(filter_hours_control, "mode_impr_hour", "
```




# Q4. (c)

## What days/hours is advertising most/least effective?

In [234…
```
days = ['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Su

daywise_tuples_ctrl = [(days[i], rates_days_ctrl[i]) for i in range(len(rates_(
sorted_daywise_tuples_ctrl = sorted(daywise_tuples_ctrl, key=lambda x: x[1])

daywise_tuples_test = [(days[i], rates_days_test[i]) for i in range(len(rates_(
sorted_daywise_tuples_test = sorted(daywise_tuples_test, key=lambda x: x[1])

hourwise_tuples_ctrl = [(i + 8, rates_hours_ctrl[i]) for i in range(len(rates_h
sorted_hourwise_tuples_ctrl = sorted(hourwise_tuples_ctrl, key=lambda x: x[1])

hourwise_tuples_test = [(i + 8, rates_hours_test[i]) for i in range(len(rates_h
sorted_hourwise_tuples_test = sorted(hourwise_tuples_test, key=lambda x: x[1])
```

In [235…
```
print("Control group conversion rates in sorted order daywise -\n")
for day in range(len(sorted_daywise_tuples_ctrl)):
    print(sorted_daywise_tuples_ctrl[day])

print("\nTest group conversion rates in sorted order daywise -\n")
for day in range(len(sorted_daywise_tuples_test)):
    print(sorted_daywise_tuples_test[day])
```

```
Control group conversion rates in sorted order daywise -

('Saturday', 1.3995801259622114)
('Tuesday', 1.4447884416924663)
('Wednesday', 1.5759312320916905)
('Friday', 1.630291874835656)
('Thursday', 2.0230473751600515)
('Sunday', 2.059496567505721)
('Monday', 2.2558537978298117)

Test group conversion rates in sorted order daywise -

('Saturday', 2.130656582320246)
('Thursday', 2.1637138485273844)
('Friday', 2.246495129778729)
('Sunday', 2.4619831900111744)
('Wednesday', 2.5355860394223564)
('Tuesday', 3.044037976720485)
('Monday', 3.3241196108697997)
```

## Days -

For the test group, the day with the most effective advertising is also Monday (Day 1). For the control group, the day with the most effective advertising is Monday (Day 1).

For the test group, the day with the least effective advertising is also Saturday (Day 6). For the control group, the day with the least effective advertising is Saturday (Day 6).

In [236…
```
print("Control group conversion rates in sorted order hourwise -\n")
for hour in range(len(sorted_hourwise_tuples_ctrl)):
    print(sorted_hourwise_tuples_ctrl[hour])
```

```
Control group conversion rates in sorted order hourwise -

(8, 1.062215477996965)
(9, 1.0815307820299502)
(23, 1.2924071082390953)
(10, 1.3468013468013467)
(11, 1.455604075691412)
(14, 1.6051364365971106)
(22, 1.6357688113413305)
(13, 1.6589861751152075)
(12, 1.6990291262135921)
(20, 1.7641597028783658)
(17, 2.0245842371655822)
(21, 2.2201665124884364)
(19, 2.4513947590870666)
(15, 2.516411378555799)
(18, 2.5177025963808024)
(16, 2.8054862842892767)
```

In [237…
```
print("Test group conversion rates in sorted order hourwise -\n")
for hour in range(len(sorted_hourwise_tuples_test)):
    print(sorted_hourwise_tuples_test[hour])
```

```
Test group conversion rates in sorted order hourwise -

(9, 1.9528890678477955)
(8, 1.9860914662894862)
(10, 2.18401238852993)
(11, 2.2469365104532377)
(23, 2.297027676881363)
(12, 2.4138998187364606)
(13, 2.5063207650873913)
(22, 2.6455026455026456)
(19, 2.6809283828722275)
(18, 2.747005023830993)
(17, 2.8537420026781732)
(14, 2.8575344343178233)
(21, 2.917459768125973)
(15, 2.9844825574612064)
(20, 3.0273647920706743)
(16, 3.089286210827795)
```

## Hours -

For the test group, the hour with the most effective advertising is also hour 16. For the control group, the hour with the most effective advertising is hour 16.

For the test group, the hour with the least effective advertising is hour 9. For the control group, the hour with the least effective advertising is hour 8.

Overall, the best time to advertise should be on Monday (Day 1) at hour 16 considering that day and hour are linearly independent.

Overall, the worst time to advertise should be on Saturday (Day 6) at hour 8 or 9 considering that day and hour are linearly independent.