1) Was the advertising campaign effective? Did additional consumers convert as a result of the ad campaign? Use an appropriate statistical test to support your conclusion. (5 points)

```
        2-sample test for equality of proportions with continuity correction

data:  xtabs(~test + converted, data = copy)[, 2:1]
X-squared = 54.006, df = 1, p-value = 1.999e-13
alternative hypothesis: two.sided
95 percent confidence interval:
 -0.009456114 -0.005928792
sample estimates:
    prop 1     prop 2
0.01785411 0.02554656
```

The p-value is less than .05. We can conclude that the campaign had a significant impact on conversion rates.

2) What is the minimum sample size of the control group (test=0) required to have a power of 0.8? Is the statistical test performed in the above question well powered? (5 points)

```
     Difference of proportion power calculation for binomial distribution (arcsine transformation)

              h = 0.05300255
              n = 5587.828
      sig.level = 0.05
          power = 0.8
    alternative = two.sided
```

The minimum sample size required is 5588.

	test	sample_size
1	0	23524
2	1	564577

The test is well powered, as the sample sizes exceed the minimum sample size.

3) Based on the total impressions (tot_impr) the customers received, the randomization done in the above A/B test is valid. Justify the statement using an appropriate test. (5 points)

```
        Welch Two Sample t-test

data:  test_group$tot_impr and control_group$tot_impr
t = 0.218, df = 25608, p-value = 0.8274
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.4972735  0.6217286
sample estimates:
mean of x mean of y
 24.82337  24.76114
```

```
  test `mean(tot_impr)`
  <int>            <dbl>
1     0             24.8
2     1             24.8
>
```

I used a two sample t test to check the randomization. The p-value was .8, indicating that the randomization is valid and there is not a difference in mean total impressions among the groups. Additionally, the mean tot_impr was the same for both groups.

4) How much more money did AdVert make by running the campaign (excluding advertising costs)? (5 points)

$180957.50. This was calculated by applying both conversion rates to the entire population, subtracting those from test 0 from test 1 to account for users who would have converted regardless of the ad. Then, I multiplied by 40$.

5) What was the cost of the ad campaign? (5 points)

$131374.64. This is total impressions * 9$ per 1000 impressions

6) Calculate the Return on Investment (ROI) of the campaign. Was the campaign profitable? (5 points)

32.23%. Yes, the campaign was profitable as ROI is positive.

7) What was the opportunity cost of including a control group, i.e., how much more could have AdVert made by not having a control group at all? (5 point)

$7238.291. This was calculated by applying the conversion rate from test 1 to the control group, then subtracting the converts and multiplying by 40.

8) What is the naïve Average Treatment Effect (ATE) of medication on side effects (ignore Age<18 column)? (5 points)

0.5041

9) What is the marginal causal effect of medication on side effects, considering the Age<18 attribute as well? Use the standardized mean (weighted average) technique or the mean potential outcome (E[Y] = E[Y1] – E[Y0]) framework to answer this question. (10 points)
0.3022789