API - 209 | Problem Set 4

Prof. Dan Levy

Due on Tuesday, September 27, 2022 at 10:00 am.

INSTRUCTIONS

To successfully complete this problem set, please follow these steps:

1. **Download this RMarkdown document file into your computer.**
2. **Insert all your answers into this document.** Guidance **here** on how to insert objects such as handwritten work or screenshot images in your answers.
3. **SAVE your work frequently**.
4. To make things easier to visualize in RStudio, you can set the view mode as "Visual" instead of as "Source" in the top left of your screen (just below the Save button).
5. Once your document is complete, please save it as a PDF by clicking the **KNIT** button.
6. Please submit an electronic copy of the PDF (and any separate requested files) to the Canvas course page.

   6.a) If you want to check a PDF version of this problem set before starting to work on it, you can always knit it. In fact, you can knit the document at any point.

   6.b) If you cannot Knit and it's time to submit the problem set, submit the RMarkdown file and make an appointment with a member of the teaching team
7. Remember to consult the R resources from math camp, particularly the HKS R cheat sheet (available **here**, which contains many of the commands needed to answer the questions in this problem set.

IDENTIFICATION

1. Your information

```
Last Name:  Chaturvedi
First Name: Shreya
```

2. Group Members (please list below the classmates you worked with on this problem set):

```
Group members: Bharath Ram, Manisha Jha
```

3. Compliance with Harvard Kennedy School Academic Code: Do you certify that my work in this problem set complies with the Harvard Kennedy School Academic Code[1] (mark with an X below)?

[1] We abide by the Harvard Kennedy School Academic code (available here) for all aspects of the course. In terms of problem sets, unless explicitly written otherwise, the norms are the following: You are free (and encouraged) to discuss problem sets with your classmates. However, you must hand in your own unique written work and code in all cases. Any copy/paste of another's work is plagiarism. In other words, you can work with your classmate(s), sitting side-by-side and going through the problem set question-by-question, but you must each type your own answers and your own code. For more details, please see syllabus.

[X] YES [ ] NO

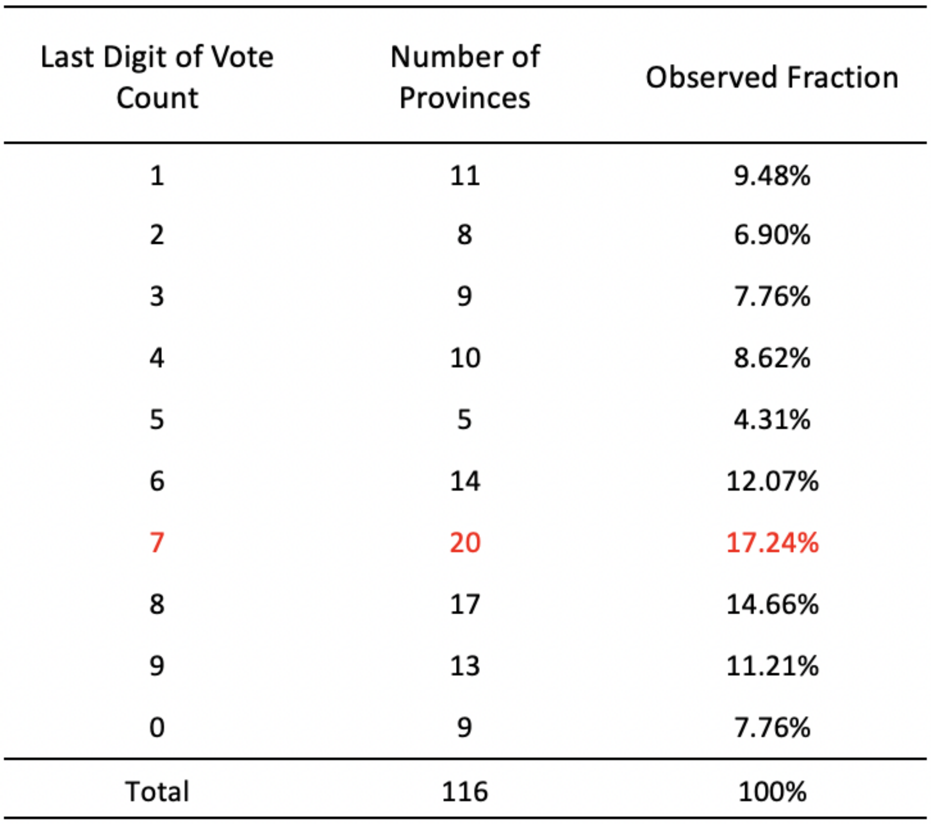
QUESTION 0 - RECORDING TIME

In an effort to understand better and more accurately the length of time that it takes you to complete problem sets, I would like to ask you to please fill in the form linked at the end of this problem set as accurately as possible. **As you go through this problem set, please keep track of the time you spend on each question and then record your time (in minutes).**

QUESTION 1 – ELECTIONS IN IRAN

On June 12, 2009, Iran held presidential elections between the incumbent Mahmoud Ahmadinejad and challenger Mir-Houssein Mousavi. The official results indicated that Ahmadinejad won with 62% of the vote. There were several allegations of fraud. One of the key arguments behind one of the allegations was that the government had made up vote counts and that this could be detected statistically. The underlying notion is that when people make up numbers they have systematic biases and that the resulting numbers exhibit a pattern. In the case of the Iranian elections, analysts looked at the patterns in the last digit of the official vote counts for Ahmadinejad (i.e., if the vote count for a province was 5,678, the last digit was 8). They looked at the vote counts for all 116 provinces in Iran and tabulated a frequency distribution of the last digit. The results are below. If no fraud had occurred, one would expect to see no systematic pattern in the distribution of the last digit. In other words, one would expect the distribution of last digit to be discrete uniform (i.e., 10% frequency for each of the digits). Yet the actual results seem to be different from this. While this difference could potentially be due to sampling fluctuations, the analysts tried to assess statistically whether the deviations were large enough to warrant suspicion of fraud. In this problem set question, we will focus on the last digit 7.

Table 1 – Distribution of Last Digit of Vote Counts (Iranian 2009 Presidential Elections)



Last Digit of Vote Count	Number of Provinces	Observed Fraction
1	11	9.48%
2	8	6.90%
3	9	7.76%
4	10	8.62%
5	5	4.31%
6	14	12.07%
7	20	17.24%
8	17	14.66%
9	13	11.21%
0	9	7.76%
Total	116	100%

1. Test the hypothesis that the proportion of vote counts that end in 7 is equal to 10%. Conduct the test in two ways:
    1. Using the sampling distribution of your estimator, and
    2. Using the distribution of your test statistic.

   In both cases report the **p-value**. Please follow the 5 steps to conduct hypothesis tests described in handout #7. Please indicate at the end whether you would reject the null hypothesis.

```
# Feel free to calculate by R or hand
```

Answer:

Enter your calculations here if done by hand.

Question 1

$H_0 : p = 0.1$

$H_A : p \neq 0.1$

$\hat{p} = 0.1724$

sampling distribution (assuming H_0)

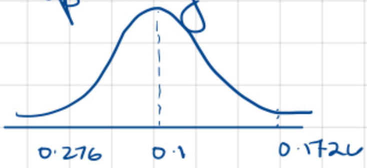
→ shape : approx. normal

→ mean : 0.1

→ std dev : $\sqrt{\dfrac{0.1 \times 0.9}{116}}$

$= 0.028$

graphically



pvalue : $p(\hat{p} \geq 0.1724) + p(\hat{p} \leq 0.276)$

$= 2\text{pnorm}(0.0276.0.1, 0.028)$

$= 0.009718$

using distribution of test statistic

$$Z = \frac{\hat{p} - p}{SE} = \frac{0.1724 - 0.1}{0.028}$$

$= 2.586$

pvalue : $2 \cdot \text{pnorm}(-2.586)$

$= 0.00971$

Since the pvalue is really small, I would reject the null hypothesis at $\alpha = 0.1, 0.05, 0.01$ → all significance levels.

$p < 0.01$

$p < 0.05$

$p < 0.1$

2. Would you conclude there was fraud in the Iranian 2009 Elections? Explain briefly (one short paragraph) in this form:

https://forms.gle/fCWECB43rP2R5JA48

NOTE: Please remember to **record the time** it took you to complete this question.

QUESTION 2 - NERDY FRIEND

Suppose a friend from college calls you and asks you how this course is going. This friend has not taken a statistics course before. After giving her your personal opinion on the instructor, his teaching techniques, and how lengthy his problem sets are (yes; I know what you are thinking right now), your friend asks you to summarize the key concepts you have studied so far in this course. (OK; maybe by now she is not your friend anymore, or maybe you argue that you don't have such nerdy friends). You decide to write her an e-mail (about 2-4 paragraphs long) explaining the key concepts we have studied so far in this course and how they relate to each other. What would you write to your friend? Make sure you include in your letter the concepts of probability, estimator, estimates, sampling distribution, confidence intervals, and hypothesis testing. Feel free to use diagrams if you think better visually.

Please write your letter in the following link:

https://forms.gle/qCJYXAGHk35FpUkHA

Please enter "Done" in this field once you have completed the form.

Done

NOTE: Please remember to **record the time** it took you to complete this question.

QUESTION 3 – ONLINE MODULE ON HYPOTHESIS TESTING

Background: The goal of this problem set question is to help you deepen your understanding of the 3 methods of **hypothesis testing** by illustrating how they link to each other. You will be asked to watch a short module and answer some questions in a quiz. The quiz results will give me information about overall performance of the class that I will use to prepare for class; your individual performance in the quiz will be registered in the system but will not count towards your grade in any way.

Instructions:

To get full credit for this question, you need to engage with the module and complete the quiz. Please make sure you **submit** your answers at the end of the quiz/survey so that they are registered.

Note: This module will likely help you understand the next question better.

The module is available here:

https://canvas.harvard.edu/courses/109224/pages/hypothesis-tests-introduction-to-this-module?module_item_id=1176559

Please watch **all** of the sub-sections of the module, and then take the quiz.

Please enter "Done" in this field once you have completed the form.

Done

NOTE: Please remember to **record the time** it took you to complete this question.

QUESTION 4 – LABOR MARKET OUTCOMES IN SOUTH AFRICA

The question asks you to explore the issue of ethnic differences in labor market outcomes in post-apartheid South Africa. In your DEV-101 and DEV-401 courses, you have examined (or will examine) various possible reasons why the labor market outcomes between different ethnic groups might differ. In this problem set question, you will empirically estimate these differences. In particular, you will examine how employment levels and earnings vary by ethnic group, education and gender.

This problem set question will allow you to continue to develop your R skills by conducting statistical analyses on a data set derived from the South Africa's Post Apartheid Labour Market Series (PALMS). For this analysis, we will focus on sample data collected in 2017. Note that the observations in the data represent a **random sample**, not the population.

The data set provided contains the following variables:

- Year – survey year (restricted to 2017 for this problem set)
- Popgroup – respondent population group. This is a numeric variable corresponding to the following categories:
  - 1 = African/Black
  - 2 = Coloured
  - 3 = Indian/Asian
  - 4 = White
  - 5 = Other
  - 9 = Unspecified
- Gender – respondent's gender. This is a numeric variable corresponding to the following categories:
  - 1 = Male
  - 2 = Female
  - 9 = Unspecified
- Age – respondent age
- Empstat1 – Employment status, using official definition of unemployed:
  - 1 = employed
  - 2 = unemployed
  - 0 = not economically active
- yrseduc – Years of education
- imputed_real – real monthly income (imputed from other measures in data set)

1. First, we need to clean the data set that will help make easier analyzing the data. After loading in the data, make the following changes:

   a. Following the guidance from math camp, recode the following variables as factors with appropriately named levels: *popgroup, gender, empstat1*.

   b. Additionally, use the 'yrseduc' variable to create a new factor variable which assigns each entry to one of the following education levels: 'Primary', 'Lower Secondary', 'Upper Secondary', 'Bachelor or Above.' [Use the following cutoffs: less than 6 years of education corresponds to primary, between 6 and 8 years corresponds to lower secondary, between 9 and 12 years corresponds to upper secondary, and greater than 12 years corresponds to Bachelor or above.]

```r
# Enter only code here. No need to print out the table
input <- read_csv("palms_clean.csv")
input <- input %>%
  mutate(gender = recode(gender, '1' = "Male", '2' = "Female", '9' = "Unspecified")) %>%
  mutate(popgroup = recode(popgroup,'1' = "African/Black",'2'="Coloured", '3'="Indian/Asian",'4'="White",
  mutate(empstat1 = recode(empstat1, '1' = "Employed", '2' = "Unemployed", '9' = "Not economically active
  mutate(yrseduc = case_when(yrseduc %in% 0:5 ~ "Primary",
                             yrseduc %in% 6:8 ~ "Lower Secondary",
                             yrseduc %in% 9:12 ~ "Upper Secondary",
                             yrseduc %in% 12:18 ~ "Bachelor or above"))

head(input)
```

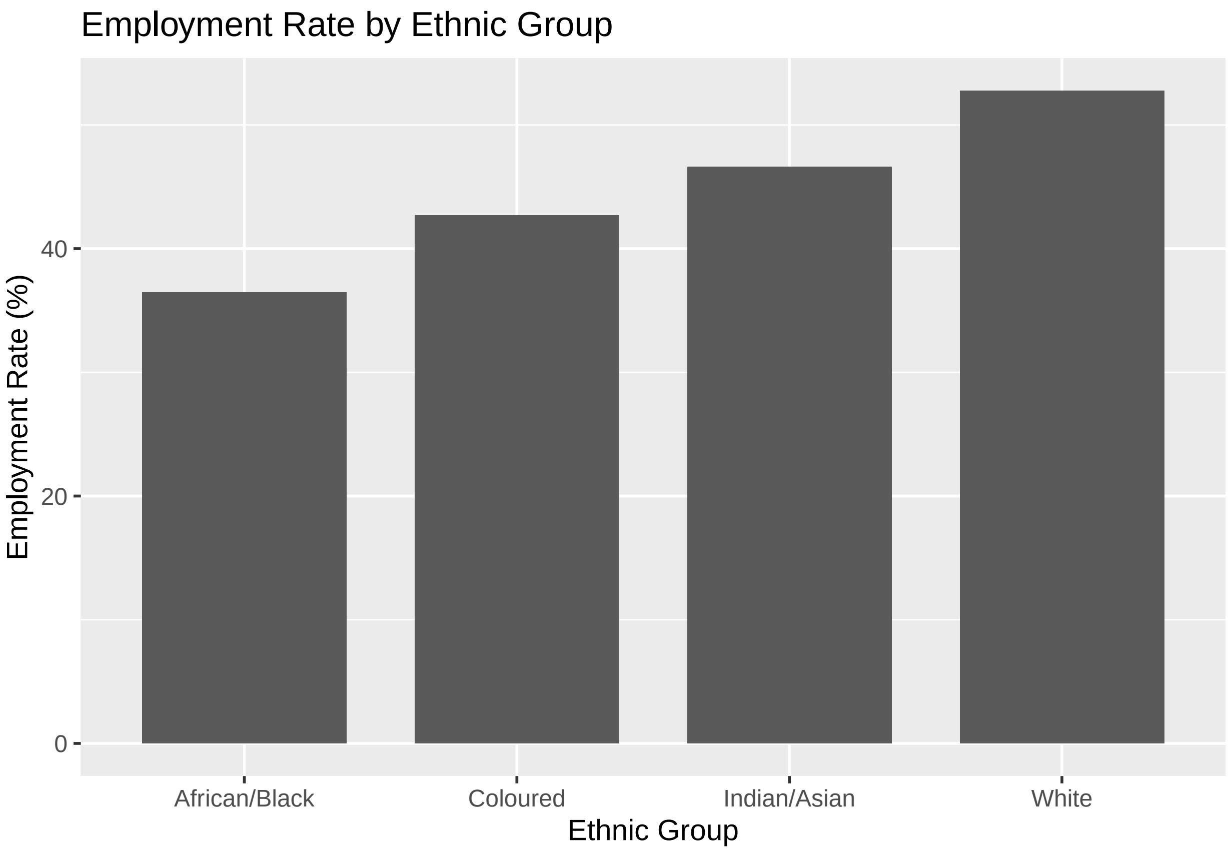
```
## # A tibble: 6 x 7
##    year popgroup      gender   age empstat1 yrseduc  input~1
##   <dbl> <chr>         <chr>  <dbl> <chr>    <chr>      <dbl>
## 1  2017 Coloured      Male      70 <NA>     Primary      NA
## 2  2017 African/Black Male      26 Employed Lower S~   3104.
## 3  2017 African/Black Female    20 Employed Lower S~   3326.
## 4  2017 Coloured      Male      25 Employed Lower S~   3104.
## 5  2017 Coloured      Female    21 Employed Upper S~   3991.
## 6  2017 Coloured      Male      99 <NA>     Upper S~     NA
## # ... with abbreviated variable name 1: imputed_real
```

Confirm that you have done the things indicated above.

I have recoded the values as indicated.

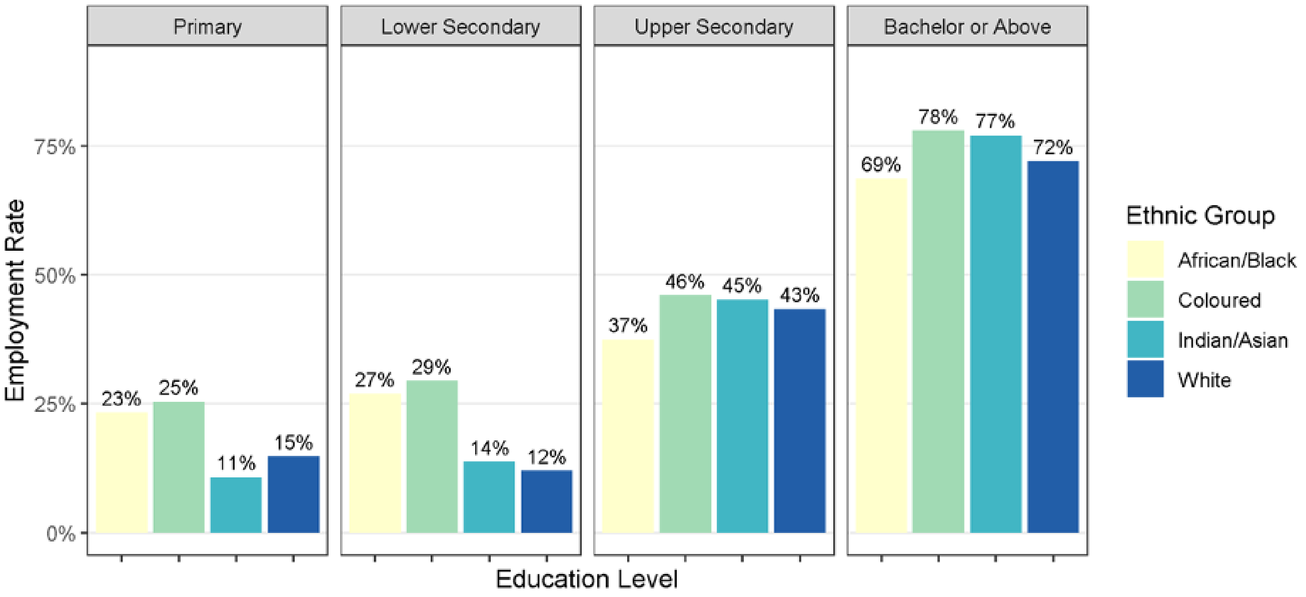
2. Compare the 4 main ethnic groups in South Africa according to their employment rate **in 2017**. Note, for purposes of this problem set, you can calculate the employment rate as the percentage of respondents in an ethnic group category in the survey who are classified as employed by the '*empstat1*' variable divided by the total number of respondents in that ethnic group category. Present your results in a table or graph (whichever you prefer).

```
# Insert only code here.

library(gt)
temp <- input %>%
  group_by(popgroup) %>%
  mutate(countall = n()) %>%
  filter(empstat1 == "Employed") %>%
  mutate(countemp1 = n()) %>%
  mutate(percent = countemp1/countall*100) %>%
  select(popgroup, percent) %>%
  distinct()

plot <- ggplot(data = temp, aes(x=popgroup,y = percent)) +
  geom_bar(stat="identity", width=0.75) +
  labs(x = "Ethnic Group", y = "Employment Rate (%)", title = "Employment Rate by Ethnic Group")
plot
```



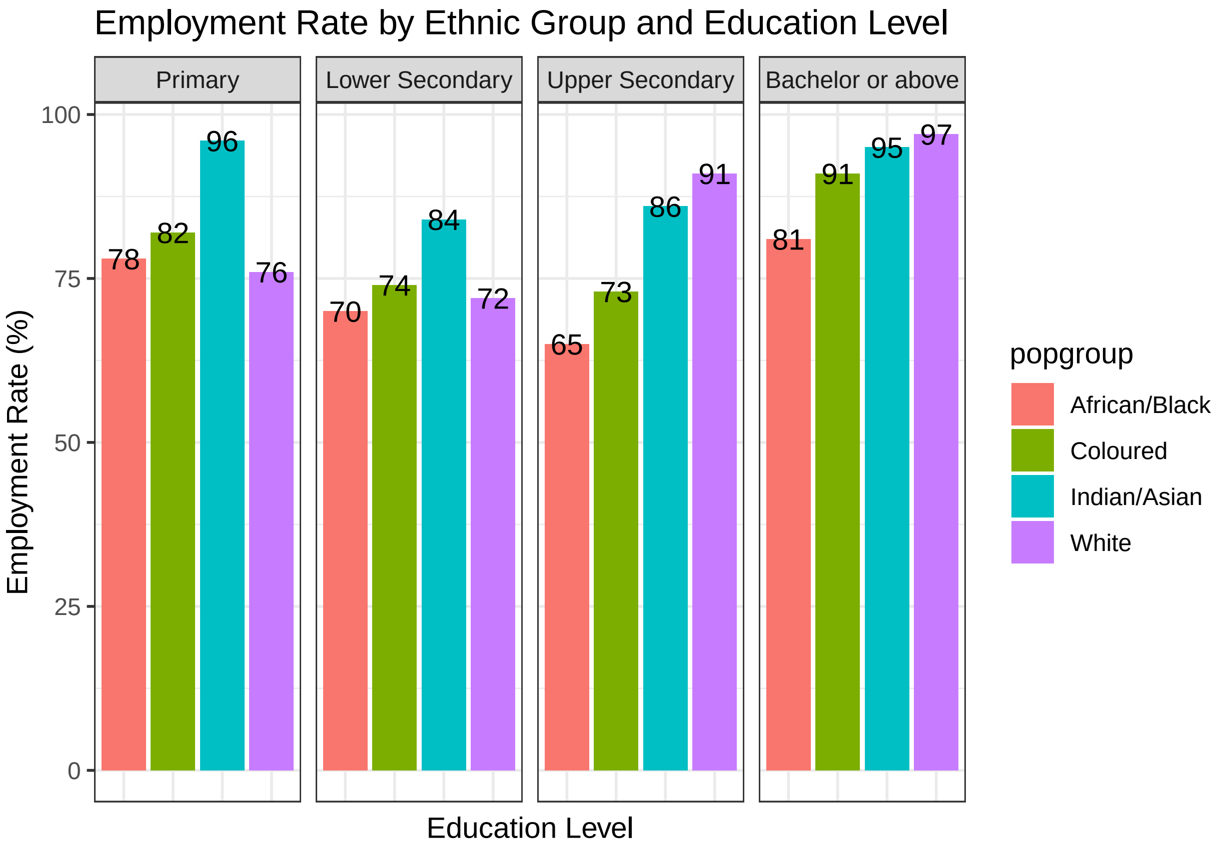
3. Produce a visual that looks similar to one recently produced by the CID's Growth Lab (and produced here in R by Casey Kearney, our previous TA), and explain your key take-aways in 2-3 sentences (or tweet).

Hint: as with most graphs, do not feel obligated to exactly replicate the visualization, but try to convey the same general information. Also, do not think of this graph as a singular object to re-create; instead identify the different "layers" you want to add to the plot and build things up layer by layer.



Source: Post Apartheid Labor Market Survey.
Data from 2017 only.

```
# Insert only code here.


input %>%
  group_by(popgroup, yrseduc) %>%
  mutate(emprate = ifelse(empstat1== "Employed", 1, 0)) %>%
  filter(yrseduc != "NA") %>%
  summarise(emprate = round(mean(emprate, na.rm = TRUE)*100,digits = 0)) %>%
  ggplot(aes(x=popgroup, y=emprate, fill=popgroup)) +
  geom_col() +
  geom_text(aes(label = emprate), vjust = 0.5) +
  facet_grid(~factor(yrseduc, levels=c("Primary", "Lower Secondary", "Upper Secondary","Bachelor or above
  theme_bw() +
  labs(x='Education Level', y='Employment Rate (%)', title='Employment Rate by Ethnic Group and Educatio
  theme(axis.text.x = element_blank(), axis.ticks.x = element_blank())
```



Answer:

Takeaways:
1. Coloured ethnic groups have the highest employment rate across education levels.

2. The employment rates increase with education levels across all ethnic groups and the employment rate jumps significantly for upper secondary and bachelors across all education groups.

---

4. Are the findings from the graph in (3) consistent with your graph/table in question (2)? If the findings are not consistent, what do you think is the cause of the inconsistency, and how might you change the visualization (or add a new one) to address any inconsistencies? Note, you do not need to create a separate plot, and can instead describe verbally any modifications you think would be helpful (but feel free to try altering the plot if you have time and want the practice!)

```
# Insert only code here.
```

Answer: The findings between the graphs in (2) and (3) are not consistent. This is because in (2) we see that the white ethnic group has the highest employment rate, whereas in (3) we see that the coloured have a greater employment rate in each of the segments. Similarly, for the comparison between Indian/Asian ethnic group and the coloured ethnic group. This is caused by the NA values in education level that are not discarded in question 2. I would address this by filtering out the NAs in the (2) graph.

---

5. Explain why it would be helpful to conduct hypothesis testing to assess your key take-aways from the analysis of these data. [2-3 sentences]

Answer: Hypothesis testing would be important to understand whether the differences in employment rates across ethnic groups is due to a systemic factor or pure random fluctuations. We could then understand if there is some key underlying difference that results in the difference - whether that is education level or something else.

---

6. **Hypothesis testing**

A: Test the null hypothesis that ***average real income*** was the same for Whites and Blacks/Africans in 2017, using each of the three methods below. Note, respondents who were not employed have incomes listed as NA. You should recode these NA values to 0 before proceeding with this analysis given that this variable is meant to measure income from labor. Please follow the 5 steps to conduct hypothesis tests described in handout #7. You should not assume the variances are equal[2].

a. p-value
b. Critical region
c. Confidence interval

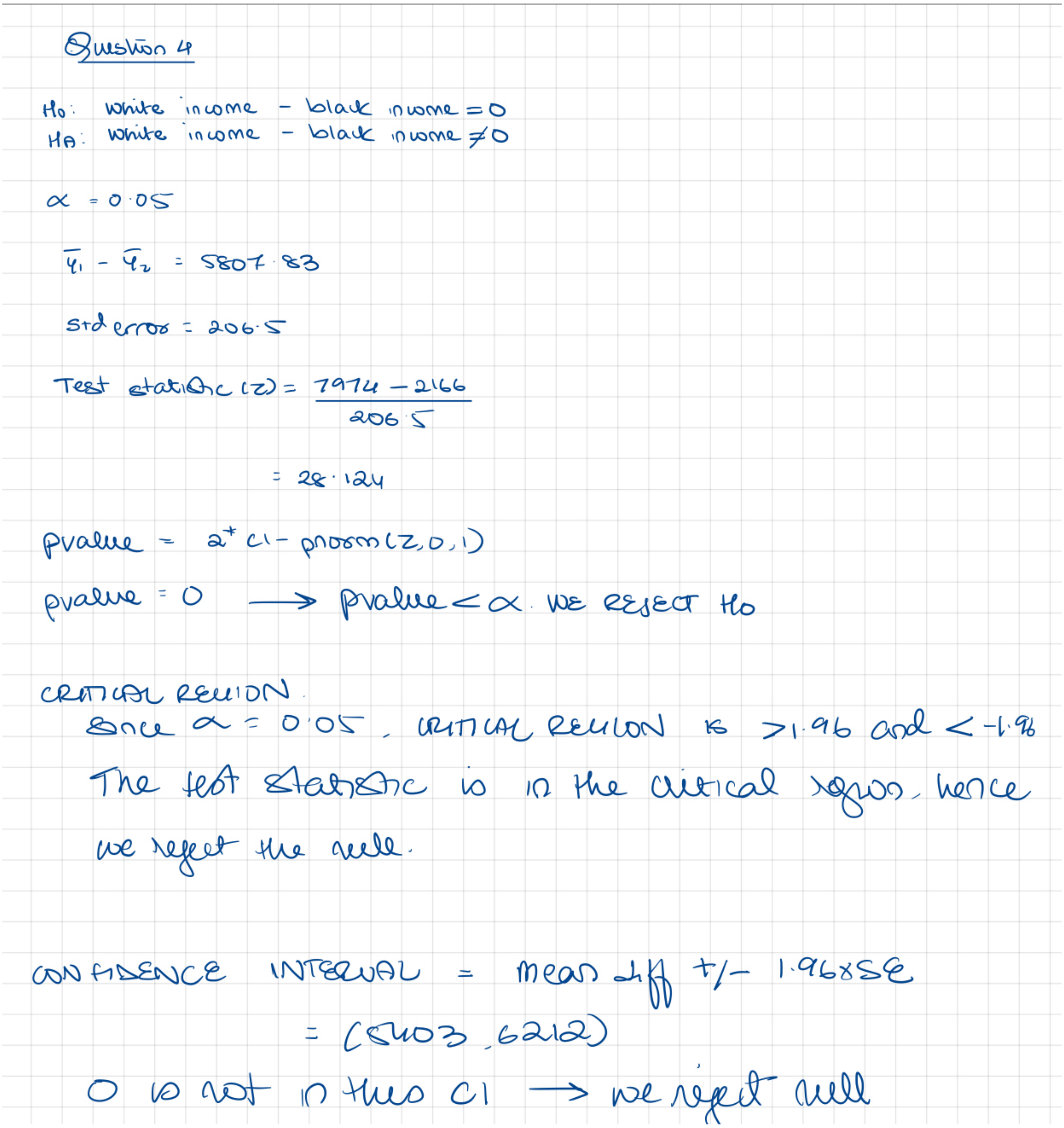
```
# Insert only code here.
input$imputed_real <- replace_na(input$imputed_real,0)
temp2 <- input %>%
  group_by(popgroup) %>%
  summarize (n(),meanincome = mean(imputed_real), sdincome = sd(imputed_real))

stderror <- sqrt((23944.4^2/13634) + (9569.24^2/154462))
Z <- ((7974 - 2166)-0)/stderror

pval1 <- 2*(1-pnorm(Z,0,1))
pval1
```

```
## [1] 0
```

Answer:

Enter your calculations here.

[2] You may use R to calculate the relevant numbers, but not to conduct the test. The online module on hypothesis testing (Question 3 of this problem set) should provide you with guidance on how to conduct hypothesis tests using the 3 methods. Note that the test statistic has a t-distribution, but given the large sample sizes, you can use the normal distribution to compute your numbers. The `pnorm()` function can be used to calculate probabilities from a normal distribution.



Question 4

Ho: white income − black income = 0
HA: white income − black income ≠ 0

$\alpha = 0.05$

$\bar{y}_1 - \bar{y}_2 = 5807.83$

std error = 206.5

Test statistic (z) = $\frac{7974 - 2166}{206.5}$

= 28.124

pvalue = 2* (1 − pnorm(z,0,1))

pvalue = 0 → pvalue < α. we reject Ho

CRITICAL REGION.

Since α = 0.05, CRITICAL REGION is >1.96 and <−1.96

The test statistic is in the critical region, hence we reject the null.

CONFIDENCE INTERVAL = mean diff +/− 1.96xSE

= (5403, 6212)

0 is not in this CI → we reject null

B: Use R to conduct the test just above. Identify in your R output the numbers that correspond to the tests you conducted in (A).

```
# Insert only code here.
#as above
```

C: Explain what the p-value in this test means. Be precise. You may use technical language.

Answer: A pvalue is the probability of observing a certain value due to some systemic underlying reason, and not pure sampling fluctuation. For example a p value of 0.05 would mean that there is a 5% chance this observation is due to sampling fluctuations, and 95% chance it is significant. In this test, the p value of 0 means that we are absolutely certain that the income difference is due to some underlying reason that is not random.

D: Express the conclusions of the test in a language that a policymaker (who is intelligent but not well-versed in statistics) can understand.

Answer: This test shows us that the difference between average white and black incomes is not at all due to any chance, but due to some underlying differences between the ethnic groups (such as possibly education etc).

NOTE: Please remember to **record the time** it took you to complete this question.

QUESTION 5 - ONLINE MODULE ON STATISTICAL POWER

Background: The goal of this problem set question is to help you prepare you for the class on statistical power. The idea is to get everyone familiar with these concepts so that we can delve deeper in class on this topic than we would be able to do if we had to go through the basics in class. Instructions: Same as in Question 3 (above)

The module is available here:

https://canvas.harvard.edu/courses/109224/modules/items/1176566

Please enter "Done" in this field once you have completed the form.

Done

NOTE: Please remember to **record the time** it took you to complete this question.

TIME USE

Please enter in the form linked below the time you spent on each question.

This information will only be used for teaching improvements; **please be candid** and report the time (in **MINUTES**) spent in each question.

The form is available here:

https://forms.gle/58nan36VMoTgxLmL8

Please enter "Done" in this field once you have completed the form.

This is a copy of your code.

```
.answer-box {
  background-color: LemonChiffon;
}
knitr::opts_chunk$set(echo = TRUE)
knitr::opts_chunk$set(options(width = 60))
knitr::opts_chunk$set(class.output = "bg-warning")

packages <- c('haven','dplyr', 'ggplot2', 'reshape2', 'tidyverse', 'pracma',
              'lubridate', 'scales', 'ggthemes', 'gt', 'dineq', 'gglorenz')
to_install <- packages[!(packages %in% installed.packages()[,"Package"])]
if(length(to_install)>0) install.packages(to_install,
                                          repos='http://cran.us.r-project.org')
lapply(packages, require, character.only=TRUE)


Last Name:  Chaturvedi
First Name: Shreya
Group members: Bharath Ram, Manisha Jha
                             [ X ] YES                 [   ] NO
# Feel free to calculate by R or hand

# Enter only code here. No need to print out the table
input <- read_csv("palms_clean.csv")
input <- input %>%
  mutate(gender = recode(gender, '1' = "Male", '2' = "Female", '9' = "Unspecified")) %>%
  mutate(popgroup = recode(popgroup,'1' = "African/Black",'2'="Coloured", '3'="Indian/Asian",'4'="White",
  mutate(empstat1 = recode(empstat1, '1' = "Employed", '2' = "Unemployed", '9' = "Not economically active
  mutate(yrseduc = case_when(yrseduc %in% 0:5 ~ "Primary",
                             yrseduc %in% 6:8 ~ "Lower Secondary",
                             yrseduc %in% 9:12 ~ "Upper Secondary",
                             yrseduc %in% 12:18 ~ "Bachelor or above"))

head(input)
# Insert only code here.

library(gt)
temp <- input %>%
  group_by(popgroup) %>%
  mutate(countall = n()) %>%
  filter(empstat1 == "Employed") %>%
  mutate(countemp1 = n()) %>%
  mutate(percent = countemp1/countall*100) %>%
  select(popgroup, percent) %>%
  distinct()

plot <- ggplot(data = temp, aes(x=popgroup,y = percent)) +
  geom_bar(stat="identity", width=0.75) +
  labs(x = "Ethnic Group", y = "Employment Rate (%)", title = "Employment Rate by Ethnic Group")
plot

# Insert only code here.


input %>%
  group_by(popgroup, yrseduc) %>%
  mutate(emprate = ifelse(empstat1== "Employed", 1, 0)) %>%
  filter(yrseduc != "NA") %>%
  summarise(emprate = round(mean(emprate, na.rm = TRUE)*100,digits = 0)) %>%
  ggplot(aes(x=popgroup, y=emprate, fill=popgroup)) +
  geom_col() +
  geom_text(aes(label = emprate), vjust = 0.5) +
  facet_grid(~factor(yrseduc, levels=c("Primary", "Lower Secondary", "Upper Secondary","Bachelor or above
  theme_bw() +
  labs(x='Education Level', y='Employment Rate (%)', title='Employment Rate by Ethnic Group and Education
  theme(axis.text.x = element_blank(), axis.ticks.x = element_blank())


# Insert only code here.

# Insert only code here.
input$imputed_real <- replace_na(input$imputed_real,0)
temp2 <- input %>%
  group_by(popgroup) %>%
  summarize (n(),meanincome = mean(imputed_real), sdincome = sd(imputed_real))

stderror <- sqrt((23944.4^2/13634) + (9569.24^2/154462))
Z <- ((7974 - 2166)-0)/stderror

pval1 <- 2*(1-pnorm(Z,0,1))
pval1

# Insert only code here.
#as above
```