

R Notebook

Dharmee Patel & Prachi Sardana

Question 1.1

```
# Since the data do not have column names we are assigning the column names manually via using the info

# Hence first we will assign the names of the columns to a vector
col_names <- c("age", "workclass", "fnlwgt", "education", "education-num", "marital-status", "occupation", "relationship", "race", "sex", "capital.gain", "capital.loss", "hours.per.week", "native.country", "income")

# Now we will read the 2 data files - adult.data & adult.test into our environment
# NOTE: when we read the files in, we will use the above vector to assign column names at the same time
adult.data = read.csv(file = "C:/Users/sanya/Downloads/adult/adult.data", sep = ",", col.names = col_names)
adult.test = read.csv(file = "C:/Users/sanya/Downloads/adult/adult.test", sep = ",", col.names = col_names)
```

Question 1.2

```
# Now that we have read both the files into our environment, we are going to combine both the data sets
# The function we will be using for this is rbind - because we are adding rows of one data frames to another
# REMEMBER: the column names have to be same for this binding as well as the number of columns
combined_data = rbind(adult.data, adult.test)

# The next step is to view the combined dataframe but since we just need to display the specifics, we are using head()

# Display rows 11, 112, 199, and 203
combined_data[c(11, 112, 199, 203),]
```

##	age	workclass	fnlwgt	education	education.num	marital.status
## 11	30	State-gov	141297	Bachelors	13	Married-civ-spouse
## 112	56	Self-emp-not-inc	335605	HS-grad	9	Married-civ-spouse
## 199	24	Self-emp-not-inc	32921	HS-grad	9	Never-married
## 203	42	Local-gov	254817	Some-college	10	Never-married

##	occupation	relationship	race	sex	capital.gain
## 11	Prof-specialty	Husband	Asian-Pac-Islander	Male	0
## 112	Other-service	Husband	White	Male	0
## 199	Sales	Not-in-family	White	Male	0
## 203	Prof-specialty	Not-in-family	White	Female	0

##	capital.loss	hours.per.week	native.country	income
## 11	0	40	India	>50K
## 112	1887	50	Canada	>50K
## 199	0	40	United-States	<=50K
## 203	1340	40	United-States	<=50K

```
# Display the first 4 columns of the combined data frame
head(combined_data,4)
```

```
##   age      workclass fnlwgt education education.num      marital.status
## 1  50 Self-emp-not-inc  83311 Bachelors           13 Married-civ-spouse
## 2  38      Private 215646    HS-grad            9      Divorced
## 3  53      Private 234721      11th             7 Married-civ-spouse
## 4  28      Private 338409 Bachelors           13 Married-civ-spouse
##           occupation  relationship  race    sex capital.gain capital.loss
## 1  Exec-managerial      Husband White   Male      0          0
## 2 Handlers-cleaners Not-in-family White   Male      0          0
## 3 Handlers-cleaners      Husband Black   Male      0          0
## 4  Prof-specialty      Wife Black Female      0          0
##   hours.per.week native.country income
## 1           13 United-States  <=50K
## 2           40 United-States  <=50K
## 3           40 United-States  <=50K
## 4           40      Cuba  <=50K
```

```
# summary(combined_data)
```

Question 1.3 & Question 1.4 subpart

Here in this part of the Question, we are taking in the specific columns mentioned, preparing the subset by removing rows which have any columns with N/A value in them. After doing that we are setting the seed to 33452 in order to obtain the same results in future. Once the seed is set, the subset is divided into training set and validating set with a ratio of 75:25

```
# Selecting specific rows of combined data
selected_rows <- combined_data[, c(1,2,5,9,10,13,14,15)]
# Replacing all the selected rows containing ? with NA
selected_rows[selected_rows == "?"] <- NA
# Omitting the na values from selected rows
selected_rows <- na.omit(selected_rows)
# Calculating the total rows
total_rows <- nrow(selected_rows)

# Setting the seed as per the question
set.seed(33452)

# Taking training ratio 75 %
training_ratio = 0.75
training_set <- round(training_ratio*total_rows)

# Create a random permutation of row indices
# sample is used to select random instances of rows with replacement
indices <- sample(1:total_rows)

# Splitting into training and validation data
training_data <- selected_rows[indices[1:training_set],]
```

```
validation_data <- selected_rows[indices[(training_set + 1):total_rows], ]
```

```
# Print the number of rows in each set of training and validation data  
cat("Training data:", nrow(training_data), "\n")
```

```
## Training data: 33923
```

```
cat("Validation data:", nrow(validation_data), "\n")
```

```
## Validation data: 11308
```

```
# print(training_data)
```

```
# train set is our training data and validation set is our validation data
```

```
train_set <- training_data
```

```
validation_set <- validation_data
```

```
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##	[9712]	"<=50K"	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"
##	[9721]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[12178]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
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##	[12196]	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	>50K"	>50K"	<=50K"	>50K"
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##	[12223]	<=50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
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##	[13033]	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	>50K"	"<=50K"	"<=50K"
##	[13042]	"<=50K"	"<=50K"	">50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[13069]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"
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##	[13114]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[13168]	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[13186]	">50K"	">50K"	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[13213]	">50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"
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##	[15382]	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
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##	[15418]	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"
##	[15427]	>50K"	>50K"	<=50K"	<=50K"	<=50K"	>50K"	>50K"	<=50K"
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##	[18811]	"<=50K"	">50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	">50K"
##	[18820]	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"
##	[18829]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
##	[18838]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	">50K"
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##	[18937]	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"
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##	[19063]	"<=50K"	">50K"	">50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"
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##	[20728]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[20791]	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	>50K"	"<=50K"	>50K"	"<=50K"
##	[20800]	"<=50K"	"<=50K"	>50K"	>50K"	>50K"	"<=50K"	>50K"	>50K"	"<=50K"
##	[20809]	"<=50K"	>50K"	>50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"	>50K"
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##	[20845]	>50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[20863]	"<=50K"	>50K"	"<=50K"	>50K"	>50K"	"<=50K"	>50K"	>50K"	"<=50K"
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##	[20890]	"<=50K"	"<=50K"	"<=50K"	>50K"	>50K"	>50K"	>50K"	"<=50K"	"<=50K"
##	[20899]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"
##	[20908]	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"
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##	[26353]	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
##	[26362]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	">50K"
##	[26371]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	">50K"	">50K"	">50K"	"<=50K"
##	[26380]	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
##	[26389]	"<=50K"	"<=50K"	"<=50K"	">50K"	">50K"	">50K"	"<=50K"	"<=50K"</

##	[26560]	>50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"
##	[26569]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[26578]	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"
##	[26587]	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"
##	[26596]	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[26605]	>50K"	<=50K"	>50K"	<=50K"	>50K"	>50K"	>50K"	>50K"	<=50K"
##	[26614]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"
##	[26623]	>50K"	<=50K"	>50K"	<=50K"	<=50K"	>50K"	>50K"	<=50K"	<=50K"
##	[26632]	<=50K"	>50K"	>50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"	>50K"
##	[26641]	<=50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"
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##	[26659]	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"
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##	[26677]	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"
##	[26686]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"
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##	[26704]	>50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[26713]	>50K"	<=50K"	>50K"	<=50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"
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##	[26776]	>50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"
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##	[26794]	>50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	>50K"	>50K"
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##	[26848]	<=50K"	>50K"	<=50K"	<=50K"	>50K"	>50K"	<=50K"	<=50K"	<=50K"
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##	[27532]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"
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##	[27559]	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"
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##	[27586]	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"
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##	[28684]	>"50K"	>"50K"	"<=50K"	"<=50K"	>"50K"	"<=50K"	"<=50K"	>"50K"
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##	[28774]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>"50K"	"<=50K"	"<=50K"
##	[28783]	>"50K"	"<=50K"	>"50K"	"<=50K"	"<=50K"	"<=50K"	>"50K"	"<=50K"
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##	[28801]	"<=50K"	"<=50K"	>"50K"	"<=50K"	"<=50K"	>"50K"	"<=50K"	>"50K"
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##	[28990]	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"
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##	[29089]	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[29143]	"<=50K"	"<=50K"	">50K"	">50K"	">50K"	">50K"	">50K"	">50K"
##	[29152]	">50K"	"<=50K"	">50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	">50K"
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##	[29233]	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
##	[29242]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
##	[29251]	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	">50K"	"<=50K"
##	[29260]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	">50K"
##	[29269]	">50K"	"<=50K"	">50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[29305]	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	">50K"	"<=50K"	"<=50K"
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##	[30934]	">50K"	"<=50K"	"<=50K"	"<=50K"	">50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
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##	[37774]	"<=50K"	"<=50K"	>50K"	"<=50K"	>50K"	"<=50K"	>50K"	"<=50K"	"<=50K"
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##	[37792]	"<=50K"	>50K"	>50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	>50K"
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##	[37828]	"<=50K"	"<=50K"	>50K"	>50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"
##	[37837]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"
##	[37846]	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	"<=50K"	>50K"	>50K"	"<=50K"
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##	[44164]	<=50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"
##	[44173]	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44182]	<=50K"	<=50K"	>50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44191]	>50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"
##	[44200]	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"
##	[44209]	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44218]	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"
##	[44227]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	>50K"	<=50K"	<=50K"
##	[44236]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"
##	[44245]	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	>50K"	<=50K"
##	[44254]	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44263]	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44272]	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44281]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44290]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"
##	[44299]	<=50K"	>50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44308]	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"
##	[44317]	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"
##	[44326]	<=50K"	<=50K"	>50K"	>50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"
##	[44335]	<=50K"	<=50K"	<=50K"	>50K"	>50K"	<=50K"	>50K"	<=50K"	<=50K"
##	[44344]	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"
##	[44353]	>50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	>50K"	<=50K"
##	[44362]	<=50K"	<=50K"	<=50K"	>50K"	<=50K"	<=50K"	<=50K"	<=50K"	<=50K"

[illegible]

```
## [45028] ">50K" "<=50K" "<=50K" ">50K" ">50K" "<=50K" "<=50K" ">50K" "<=50K"
## [45037] "<=50K" ">50K" "<=50K" "<=50K" ">50K" ">50K" "<=50K" "<=50K" "<=50K"
## [45046] ">50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K"
## [45055] ">50K" "<=50K" ">50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K"
## [45064] "<=50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K"
## [45073] ">50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K"
## [45082] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K"
## [45091] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K"
## [45100] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K"
## [45109] ">50K" "<=50K" ">50K" ">50K" ">50K" ">50K" "<=50K" "<=50K" ">50K"
## [45118] ">50K" "<=50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K"
## [45127] "<=50K" "<=50K" "<=50K" ">50K" ">50K" "<=50K" "<=50K" "<=50K" ">50K"
## [45136] ">50K" ">50K" "<=50K" "<=50K" ">50K" ">50K" "<=50K" "<=50K" "<=50K"
## [45145] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K"
## [45154] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K"
## [45163] "<=50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K"
## [45172] "<=50K" ">50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" ">50K"
## [45181] "<=50K" "<=50K" ">50K" "<=50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K"
## [45190] "<=50K" "<=50K" ">50K" "<=50K" ">50K" "<=50K" "<=50K" "<=50K" ">50K"
## [45199] ">50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" ">50K" "<=50K" ">50K"
## [45208] ">50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K" "<=50K" "<=50K"
## [45217] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" "<=50K"
## [45226] "<=50K" "<=50K" "<=50K" "<=50K" "<=50K" ">50K"
```

Question 1.4

Now we have to do Naive Bayes Classification but before doing that we need to convert the continuous variables into categorical variables but by binning the variable into equal bin sizes. This binning is to be done in columns of both the data sets - training as well as testing. Since the data range spans from 0 to 100 , a bin size of 10 was selected to create manageable number of bins for each columns.

```
# Using the Naive Bayes Classification algorithm from the KLaR package, build a binary classifier that

# Before we perform Naive Bayes Classification algorithm, we need to work a little on our data in order
# Converting the 'age' column to numeric type
#train_set$age <- as.numeric(train_set$age)

# Converting the train_set columns - age, education, hours per week into categorical variable by using
train_set$age <- cut(train_set$age, breaks = seq(0, 100, by = 10), labels = c("0-9", "10-19", "20-29",

train_set$education.num <- cut(train_set$education.num, breaks = seq(0,30, by = 10), labels = c("0-9",

train_set$hours.per.week <- cut(train_set$hours.per.week, breaks = seq(0,100, by = 10), labels = c("0-9",

# Converting the validation_set columns - age, education, hours per week into categorical variable by u
# Converting the 'age' column to numeric type
#validation_set$age <- as.numeric(validation_set$age)
#print(max(selecting_col$age))

# Binning for the 'age' column (adjust as needed)
validation_set$age <- cut(validation_set$age, breaks = seq(0, 100, by = 10), labels = c("0-9", "10-19",
```



```
validation_set$education.num <- cut(validation_set$education.num, breaks = seq(0,30, by = 10), labels =
validation_set$hours.per.week <- cut(validation_set$hours.per.week, breaks = seq(0,100, by = 10), label
```

Question 1.4

After transforming continuous variable to categorical variable, we need to convert make few columns to factor and to establish a binary classifier for out income column. Since we have more than one column to convert to factors, we choose to first select the columns and assign to a variable and then use a loop to convert each column to factor in both training set and testing set

The rows with N/A values have been already eliminated when we selected the data to avoid any chances of error or code breakdown. Here in this part of the question, we are required to used KlaR package for performing Naive Bayes Classification. Naive Bayes Classification is a supervised classification algorithm which gives probability of occurrence of event B given that the event A already occurred. This algorithm is called Naive because this classifier is making assumption about the probabilities of occurrence of a feature based on the occurrence of other features. The purpose of using Naive Bayes Classification is to be able to predict whether a person earns more than 50K or less than 50K by looking at the other given columns only (meaning that the actual income is missing and we need to make a prediction with values from other such as age, family size, occupation etc.)

```
# Since we have to use the Naive Bayes Classification from the KlaR library, we will have to first load
library(klaR)
```

```
## Loading required package: MASS
```

```
# Removing income column
train_features <- train_set[, -which(names(train_set) == "income")]
#print(train_features)

validation <- validation_set[, -which(names(validation_set) == "income")]
# print(validation)

#validation_set$native.country <- factor(validation_set$native.country, levels = levels(train_set$native.country))

# Train the Naive Bayes model
m <- NaiveBayes(train_features, train_set$income)

# Make predictions on the validation set
predictions <- predict(m, validation)
# print(predictions)
```

Question 1.5 & Question 1.6

Now we need to build a confusion matrix - the purpose of this confusion matrix is to determine the performance of the classifier we created in question 1.4. It gives all the possible outcomes in following order - true positive, true negative, false positive, & false negative.

After that we need to calculate the accuracy and precision of the model to draw significant conclusion

```

# Build a confusion matrix for the classifier from (4) using your validation data and comment on it, e.
# Import gmodels library
library(gmodels)

```

```
## Warning: package 'gmodels' was built under R version 4.2.3
```

```

binary_class_labels <- predictions$class
# Assuming you've already defined binary_class_labels and validation_set$income

# Create a confusion matrix
confusion_matrix_nb <- table(Predicted = binary_class_labels, Actual = validation_set$income)
# Generating cross table
crosstab <- CrossTable(binary_class_labels, validation_set$income,
  prop.chisq = FALSE, prop.c = FALSE, prop.r = FALSE,
  dnn = c('predicted', 'actual'))

```

```

##
##
##      Cell Contents
## |-----|
## |                      N |
## |      N / Table Total |
## |-----|
##
##
## Total Observations in Table:  11308
##
##
##      | actual
## predicted |      <=50K |      >50K | Row Total |
## -----|-----|-----|-----|
##      <=50K |      7642 |      1546 |      9188 |
##      |      0.676 |      0.137 |      |
## -----|-----|-----|-----|
##      >50K |      866 |      1254 |      2120 |
##      |      0.077 |      0.111 |      |
## -----|-----|-----|-----|
## Column Total |      8508 |      2800 |      11308 |
## -----|-----|-----|-----|
##
##

```

```

# Calculate accuracy
accuracy_nb <- sum(diag(confusion_matrix_nb)) / sum(confusion_matrix_nb)

# Calculate precision
precision_nb <- confusion_matrix_nb[1, 1] / sum(confusion_matrix_nb[1, ])
recall_nb <- confusion_matrix_nb[1, 1] / sum(confusion_matrix_nb[, 1])

# Print the accuracy in percent
cat("Accuracy:", round(accuracy_nb * 100, 2), "%\n")

```

```
## Accuracy: 78.67 %
```

```
cat("Precision:", round(precision_nb * 100, 2), "%\n")
```

```
## Precision: 83.17 %
```

```
# F1 score for Naive Baye's
```

```
f1_score_nb <- 2 * (precision_nb * recall_nb) / (precision_nb + recall_nb)
```

```
cat("F1score for Naive Bayes model:", round(f1_score_nb * 100, 2), "%\n")
```

```
## F1score for Naive Bayes model: 86.37 %
```

Based on the naive bayes model confusion matrix, accuracy which means that the model correctly predicts the 79% of total instances in the dataset. Precision (True Positives/True Positives+False Positives) is 46% which measures the accuracy of positive predictions made by the model. The model predicted '>50K', 46.47% of them were indeed '>50K' in actuality. Recall (True positives / True positives + False negatives) is 83% which measures the ability to correctly identify the positive instances. The F1 score is the harmonic mean of precision and recall. Here the F1 score is 86.73%. It signifies the balance between precision and recall. Higher F1 score indicate the better model performance. TP(True positives) - These are the correctly predicted positive instances(number of instances where the model predicted >50K). Total true positives = 7662 TN(True negatives) - These are the correctly predicted negative instances(number of instances where the model predicted '<=50K' correctly). Total true negatives = 1302 False Positives (FP) -These are the instances that were predicted as '>50K' (positive class) incorrectly. The number of instances where the model predicted '>50K' while the actual class was '<=50K', which is 1500 False negatives (FN) - These are the instances that were predicted as '<=50K' (negative class) incorrectly. In this case, the number of instances where the model predicted '<=50K' while the actual class was '>50K', which is 844

Question 1.7

Now we will have to create a full logistic regression model by taking in the features from Question 4. The function used in for this step is glm() - glm allows us to establish a linear relationship between 2 factors even though there is no as such linear relationship between those factors

```
# Create a full logistic regression model of the same features as in (4) (i.e., do not eliminate any fe  
# Create a logistic regression model  
# glm() function handles categorical variables automatically by creating dummy variables (also known as  
logistic_model <- glm(income ~ ., data = train_set, family = binomial)  
summary(logistic_model)
```

```
##
```

```
## Call:
```

```
## glm(formula = income ~ ., family = binomial, data = train_set)
```

```
##
```

```
## Deviance Residuals:
```

```
##      Min       1Q   Median       3Q      Max
```

```
## -1.9771  -0.6886  -0.3746  -0.0125   3.8928
```

```
##
```

```
## Coefficients:
```

```
##
```

```
## (Intercept)
```

```
Estimate Std. Error z value Pr(>|z|)  
-8.23419    1.16547  -7.065 1.61e-12
```

## age20-29	4.30248	1.00159	4.296	1.74e-05
## age30-39	5.61513	1.00112	5.609	2.04e-08
## age40-49	6.07158	1.00114	6.065	1.32e-09
## age50-59	6.16531	1.00134	6.157	7.41e-10
## age60-69	5.85873	1.00248	5.844	5.09e-09
## age70-79	5.84171	1.01051	5.781	7.43e-09
## age80-89	5.35042	1.04372	5.126	2.96e-07
## workclassLocal-gov	-0.43098	0.08915	-4.835	1.33e-06
## workclassNever-worked	-9.22429	176.32851	-0.052	0.958279
## workclassPrivate	-0.54392	0.07525	-7.228	4.89e-13
## workclassSelf-emp-inc	0.15076	0.09859	1.529	0.126217
## workclassSelf-emp-not-inc	-0.82958	0.08782	-9.446	< 2e-16
## workclassState-gov	-0.60338	0.10026	-6.018	1.77e-09
## workclassWithout-pay	-2.26883	1.12899	-2.010	0.044472
## education.num10-19	1.28220	0.03016	42.520	< 2e-16
## raceAsian-Pac-Islander	0.56734	0.22542	2.517	0.011842
## raceBlack	0.07241	0.18920	0.383	0.701923
## raceOther	0.42103	0.27854	1.512	0.130650
## raceWhite	0.64572	0.18025	3.582	0.000340
## sexMale	1.08458	0.03725	29.113	< 2e-16
## hours.per.week10-19	-0.05077	0.19386	-0.262	0.793387
## hours.per.week20-29	0.04481	0.18783	0.239	0.811454
## hours.per.week30-39	0.74370	0.16843	4.415	1.01e-05
## hours.per.week40-49	1.34599	0.16987	7.923	2.31e-15
## hours.per.week50-59	1.40657	0.17319	8.122	4.60e-16
## hours.per.week60-69	1.17895	0.19053	6.188	6.10e-10
## hours.per.week70-79	1.26413	0.21178	5.969	2.39e-09
## hours.per.week80-89	1.37999	0.27517	5.015	5.30e-07
## hours.per.week90-99	0.83409	0.27257	3.060	0.002213
## native.countryCanada	-0.26301	0.58065	-0.453	0.650577
## native.countryChina	-0.72648	0.59135	-1.229	0.219259
## native.countryColumbia	-2.41935	0.76903	-3.146	0.001655
## native.countryCuba	-0.88869	0.59743	-1.488	0.136876
## native.countryDominican-Republic	-2.18497	0.76130	-2.870	0.004104
## native.countryEcuador	-1.32659	0.80351	-1.651	0.098738
## native.countryEl-Salvador	-1.54111	0.66499	-2.318	0.020476
## native.countryEngland	-0.28698	0.59577	-0.482	0.630024
## native.countryFrance	-0.05598	0.74494	-0.075	0.940102
## native.countryGermany	-0.73671	0.58496	-1.259	0.207879
## native.countryGreece	-0.64562	0.67258	-0.960	0.337103
## native.countryGuatemala	-2.21669	0.90794	-2.441	0.014629
## native.countryHaiti	-0.97357	0.72008	-1.352	0.176370
## native.countryHoland-Netherlands	-11.79250	535.41144	-0.022	0.982428
## native.countryHonduras	-0.96421	0.97430	-0.990	0.322349
## native.countryHong	-0.18937	0.73982	-0.256	0.797975
## native.countryHungary	-0.46390	0.86876	-0.534	0.593357
## native.countryIndia	-0.59884	0.57193	-1.047	0.295081
## native.countryIran	-0.23073	0.63832	-0.361	0.717749
## native.countryIreland	0.04358	0.69895	0.062	0.950286
## native.countryItaly	-0.64728	0.61120	-1.059	0.289584
## native.countryJamaica	-0.83844	0.67982	-1.233	0.217453
## native.countryJapan	-0.53054	0.60334	-0.879	0.379217
## native.countryLaos	-1.50433	0.97937	-1.536	0.124533
## native.countryMexico	-2.16543	0.57100	-3.792	0.000149

## native.countryNicaragua	-1.60481	0.82434	-1.947	0.051562
## native.countryOutlying-US(Guam-USVI-etc)	-12.72933	121.93785	-0.104	0.916858
## native.countryPeru	-1.54861	0.78809	-1.965	0.049411
## native.countryPhilippines	-0.36911	0.55340	-0.667	0.504784
## native.countryPoland	-1.13636	0.64454	-1.763	0.077891
## native.countryPortugal	-1.36589	0.69447	-1.967	0.049206
## native.countryPuerto-Rico	-1.19984	0.61118	-1.963	0.049627
## native.countryScotland	-1.70096	0.98155	-1.733	0.083108
## native.countrySouth	-1.44687	0.62080	-2.331	0.019772
## native.countryTaiwan	-0.26384	0.62676	-0.421	0.673792
## native.countryThailand	-1.36736	0.79618	-1.717	0.085906
## native.countryTrinidad&Tobago	-2.08505	1.21185	-1.721	0.085332
## native.countryUnited-States	-0.69913	0.54151	-1.291	0.196676
## native.countryVietnam	-2.12023	0.75712	-2.800	0.005104
## native.countryYugoslavia	-0.12038	0.77796	-0.155	0.877031
##				
## (Intercept)	***			
## age20-29	***			
## age30-39	***			
## age40-49	***			
## age50-59	***			
## age60-69	***			
## age70-79	***			
## age80-89	***			
## workclassLocal-gov	***			
## workclassNever-worked				
## workclassPrivate	***			
## workclassSelf-emp-inc				
## workclassSelf-emp-not-inc	***			
## workclassState-gov	***			
## workclassWithout-pay	*			
## education.num10-19	***			
## raceAsian-Pac-Islander	*			
## raceBlack				
## raceOther				
## raceWhite	***			
## sexMale	***			
## hours.per.week10-19				
## hours.per.week20-29				
## hours.per.week30-39	***			
## hours.per.week40-49	***			
## hours.per.week50-59	***			
## hours.per.week60-69	***			
## hours.per.week70-79	***			
## hours.per.week80-89	***			
## hours.per.week90-99	**			
## native.countryCanada				
## native.countryChina				
## native.countryColumbia	**			
## native.countryCuba				
## native.countryDominican-Republic	**			
## native.countryEcuador	.			
## native.countryEl-Salvador	*			
## native.countryEngland				

```
## native.countryFrance
## native.countryGermany
## native.countryGreece
## native.countryGuatemala      *
## native.countryHaiti
## native.countryHoland-Netherlands
## native.countryHonduras
## native.countryHong
## native.countryHungary
## native.countryIndia
## native.countryIran
## native.countryIreland
## native.countryItaly
## native.countryJamaica
## native.countryJapan
## native.countryLaos
## native.countryMexico          ***
## native.countryNicaragua       .
## native.countryOutlying-US(Guam-USVI-etc)
## native.countryPeru            *
## native.countryPhilippines
## native.countryPoland          .
## native.countryPortugal        *
## native.countryPuerto-Rico     *
## native.countryScotland        .
## native.countrySouth           *
## native.countryTaiwan
## native.countryThailand         .
## native.countryTrinidad&Tobago .
## native.countryUnited-States
## native.countryVietnam         **
## native.countryYugoslavia
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##    Null deviance: 37992  on 33922  degrees of freedom
## Residual deviance: 28951  on 33853  degrees of freedom
## AIC: 29091
##
## Number of Fisher Scoring iterations: 12
```

```
# Make predictions and evaluate the model
logistic_predictions <- predict(logistic_model,validation , type = "response")
```

Question 1.8

```
# Build a confusion matrix and calculate the overall accuracy as well as precision using the validation
# Convert predictions to binary values based on a threshold (e.g., 0.5)
threshold <- 0.5
```

```
logistic_predictions_binary <- ifelse(logistic_predictions > threshold, 1, 0)
logistic_predictions_labels <- ifelse(logistic_predictions_binary == 1, '>50K', '<=50K')

# Create a confusion matrix
confusion_matrix_log <- table(Predicted = logistic_predictions_labels, Actual = validation_set$income)
print(confusion_matrix_log)
```

```
##           Actual
## Predicted <=50K >50K
##      <=50K  7934 1736
##      >50K    574 1064
```

```
# Calculate overall accuracy
accuracy_log <- sum(diag(confusion_matrix_log)) / sum(confusion_matrix_log)

# Calculate precision
precision_log <- confusion_matrix_log[1, 1] / sum(confusion_matrix_log[1, ])
# Calculating recall based on confusion matrix
recall_log <- confusion_matrix_log[1, 1] / sum(confusion_matrix_log[, 1])

# Print the accuracy and precision
cat("Overall Accuracy:", round(accuracy_log * 100, 2), "%\n")
```

```
## Overall Accuracy: 79.57 %
```

```
cat("Precision:", round(precision_log * 100, 2), "%\n")
```

```
## Precision: 82.05 %
```

```
# F1 score for Logistic regression
f1_score_log <- 2 * (precision_log * recall_log) / (precision_log + recall_log)
cat("F1score for Logistic regression model:", round(f1_score_log * 100, 2), "%\n")
```

```
## F1score for Logistic regression model: 87.29 %
```

The overall accuracy is 79.92 % indicating the proportion of correctly predicted instances (both positive and negative) out of the total instances. Nearly 80% accuracy might suggest that the model is doing reasonably well in predicting both '>50K' and '<=50K' income classes. A precision of 82% indicates that when the model predicts '>50K', only about 82% of those predictions are correct which means that there are high false positives (instances predicted as '>50K' that are actually '<=50K').

Question 1.9 & Question 1.10

Now we need to make a Decision tree model using rpart for predicting income category and with that we are establishing another confusion matrix and determining its precision and accuracy

```
# Create a Decision Tree model from rpart package, build a classifier that predicts whether an individual
# Load the required library
library(rpart)
```

```
## Warning: package 'rpart' was built under R version 4.2.3
```

```
# Create a Decision Tree model
model_decision_tree <- rpart(income ~ ., data = train_set, method = "class")

# Make predictions on the validation set
tree_predictions <- predict(model_decision_tree, validation, type = "class")

# Create a confusion matrix
confusion_matrix_dec <- table(Predicted = tree_predictions, Actual = validation_set$income)

# Display the confusion matrix
print(confusion_matrix_dec)
```

```
##           Actual
## Predicted <=50K >50K
##      <=50K  7685 1590
##      >50K    823 1210
```

```
# Calculate overall accuracy
accuracy_dec <- sum(diag(confusion_matrix_dec)) / sum(confusion_matrix_dec)

# Calculating precision for decision tree model
precision_dec <- confusion_matrix_dec[1,1] / sum(confusion_matrix_dec[1,])
# Calculating recall for decision tree model
recall_dec <- confusion_matrix_dec[1,1] / sum(confusion_matrix_dec[, 1 ])

# Print the accuracy and precision
cat("Overall Accuracy:", round(accuracy_dec * 100, 2), "%\n")
```

```
## Overall Accuracy: 78.66 %
```

```
cat("Precision:", round(precision_dec * 100, 2), "%\n")
```

```
## Precision: 82.86 %
```

```
# F1 score for Decision tree
f1_score_dec <- 2 * (precision_dec * recall_dec) / (precision_dec + recall_dec)
cat("F1 score for Decision tree model:", round(f1_score_dec * 100, 2), "%\n")
```

```
## F1 score for Decision tree model: 86.43 %
```

The accuracy of 79.55% indicates the proportion of correctly predicted instances (both positive and negative) out of the total instances. The decision tree model has a decent overall accuracy but shows room for improvement in precision, especially in correctly identifying '>50K' instances. A precision of 83.42 % suggests that when the model predicts '>50K', only about 83.42 % of those predictions are correct. There are relatively high number of false positives (instances predicted as '>50K' that are actually '<=50K').

Question 1.11 & Question 1.12

```
# 1.11 - Build a function called predictEarningsClass() that predicts whether an individual makes more

# Function to predict earnings class using ensemble model
predictEarningsClass <- function(data) {
  # Predictions from Naive Bayes
  nb_predictions <- predict(m, data)

  # Predictions from Logistic Regression
  logistic_predictions <- predict(logistic_model, data, type = "response")
  logistic_predictions_binary <- ifelse(logistic_predictions > threshold, 1, 0)
  logistic_predictions_labels <- ifelse(logistic_predictions_binary == 1, '>50K', '<=50K')

  # Predictions from Decision Tree
  tree_predictions <- predict(model_decision_tree, data, type = "class")

  # Combine the predictions and calculate majority vote
  predictions <- cbind(nb_predictions$class, logistic_predictions_labels, tree_predictions)
  majority_vote <- apply(predictions, 1, function(row) {
    ifelse(sum(row == 1) > length(row) / 2, '>50K', '<=50K')
  })

  return(majority_vote)
}

# 1.12 - Using the ensemble model from (11), predict whether a 38-year-old black female adult who is pr
# Data for the individual to predict
new_data <- data.frame(
  age = 38,
  workclass = "Private",
  fnlwgt = 1, # Provide an appropriate value for fnlwgt
  education = "Bachelors",
  education.num = 13,
  marital.status = "Never-married", # Provide an appropriate value for marital status
  occupation = "Exec-managerial", # Provide an appropriate value for occupation
  relationship = "Not-in-family", # Provide an appropriate value for relationship
  race = "Black",
  sex = "Female",
  capital.gain = 0, # Provide an appropriate value for capital gain
  capital.loss = 0, # Provide an appropriate value for capital loss
  hours.per.week = 40,
  native.country = "Peru"
)

# Binning for the 'age' column (adjust as needed) in new data
new_data$age <- cut(new_data$age, breaks = seq(0, 100, by = 10), labels = c("0-9", "10-19", "20-29", "30-39", "40-49", "50-59", "60-69", "70-79", "80-89", "90-99"))

# Binning for education.num column in new data
new_data$education.num <- cut(new_data$education.num, breaks = seq(0, 30, by = 10), labels = c("0-9", "10-19", "20-29", "30-39", "40-49", "50-59", "60-69", "70-79", "80-89", "90-99"))
```

```

# Binning for hours per week column in new data
new_data$hours.per.week <- cut(new_data$hours.per.week, breaks = seq(0,100, by = 10), labels = c("0-9",

# List of column names to convert to factors for new data
columns_to_convert <- c("workclass", "fnlwgt","education","marital.status","occupation","relationship",

# Convert the specified columns to factors in the test data
for (col in columns_to_convert) {
  new_data[[col]] <- as.factor(new_data[[col]])
}

#print(new_data)

# Predict income class using the ensemble model
individual_prediction <- predictEarningsClass(new_data)
cat("Predicted income class:", ifelse(individual_prediction == 1, ">50K", "<=50K"), "\n")

```

```
## Predicted income class: <=50K
```

```

validation_prediction <- predictEarningsClass(validation_set)
# Create a confusion matrix
confusion_matrix_ensemble <- table(Predicted = validation_prediction, Actual = validation_set$income)
print(confusion_matrix_ensemble)

```

```

##           Actual
## Predicted <=50K >50K
##           <=50K 1133 1442
##           >50K  7375 1358

```

```

# Calculate accuracy
accuracy_ensemble <- sum(diag(confusion_matrix_ensemble)) / sum(confusion_matrix_ensemble)

# Calculate precision
precision_ensemble <- confusion_matrix_ensemble[1,1] / sum(confusion_matrix_ensemble[1,])

# Calculating recall for ensemble model
recall_ensemble <- confusion_matrix_ensemble[1,1] / sum(confusion_matrix_ensemble[, 1 ])

# Calculating F1 score for ensemble
f1_score_ensemble <- 2 *(precision_ensemble * recall_ensemble) / (precision_ensemble + recall_ensemble)

# Print the accuracy and precision
#cat("Overall Accuracy:", round(accuracy_ensemble * 100, 2), "%\n")
#cat("Precision:", round(precision_ensemble * 100, 2), "%\n")

cat("F1 score for Ensemble model:", round(f1_score_ensemble * 100, 2), "%\n")

```

```
## F1 score for Ensemble model: 20.45 %
```

Based on the ensemble model, a 38 year old female adult who is privately employed, has 13 years of education and who immigrated from Peru earns more than 50k.

Question 1.13

The following chunk of code is doing the work of predicting which model is doing the best prediction. The model which scored the maximum for F1 score is considered for this label.

```
# Calculate the F1-Score for the ensemble from (11) using the validation data. How does its performance

f1_scores <- c(
  Ensemble = f1_score_ensemble,
  NaiveBayes = f1_score_nb,
  DecisionTree = f1_score_dec,
  LogisticRegression = f1_score_log
)

# Find the best model with the highest F1-Score
best_model <- names(f1_scores)[which.max(f1_scores)]

# Print the F1-Scores and compare the models
cat("F1-Scores:\n")
```

```
## F1-Scores:
```

```
cat(paste(names(f1_scores), ":", round(f1_scores, 4), "\n"))
```

```
## Ensemble : 0.2045
## NaiveBayes : 0.8637
## DecisionTree : 0.8643
## LogisticRegression : 0.8729
```

```
cat("\nBest Model: ", best_model, " (F1-Score: ", round(f1_scores[best_model], 4), ")\n")
```

```
##
## Best Model: LogisticRegression (F1-Score: 0.8729 )
```

The LogisticRegression has the highest F1 score. The higher the F1 score, the better the model accuracy.

Problem 2

Question 2

Question 2.1

Firstly we have loaded the dataset into the environment and called it as energy.df

```
energy.df <- read.csv("C:/Users/sanya/Downloads/large-scale+wave+energy+farm/WEC_Perth_49.csv", header = 1)
#str(energy.df)

# Checking for NA in energy.df
#k <- any(is.na(energy.df))
#print(k)
#summary(energy.df)
```

#Question2.2 subpart Identification of Outliers There are outliers present in the energy.df dataframe in more than one feature column. In order to identify the outliers, we first created a generic function - the task of this function is to take in one column of the dataframe, calculate z-score of that feature column by calculating z-score and mean of the column. If the z-score is more than 3 standard deviations away then that value is considered an outlier for that column.

*# Since it is required to find Outliers for all the numeric columns, it is important to make a generic function.
In order for the function to be called on all the numeric columns of the data set, the function have*

```
outlier <- function(column){  
  ## first calculate mean and sd for column  
  mean_val <- mean(column)  
  sd_val <- sd(column)  
  # print(column) # unhash to check values are being brought in  
  ## now calculate z-score for column using mean and sd calculated above  
  z_val <- abs((column - mean_val) / sd_val)  
  # print(z_val)  
  
  ## find outliers  
  
  outliers <- which(z_val > 3)  
  return(outliers)  
}  
  
for (column in colnames(energy.df)){  
  outlier_list <- outlier(energy.df[,column])  
  # print(outlier_list) # unhash to print outlier list to verify  
  
  if (length(outlier_list) > 0){  
    print(paste("The column", column, "has ", length(outlier_list), "outliers present!"))  
    # print(paste("These outliers are at: ", paste(outlier_list, collapse = ", ")))  
  } else{  
    next  
  }  
}
```

```
## [1] "The column Y1 has 684 outliers present!"  
## [1] "The column Y2 has 561 outliers present!"  
## [1] "The column Y3 has 658 outliers present!"  
## [1] "The column Y4 has 161 outliers present!"  
## [1] "The column Y5 has 34 outliers present!"  
## [1] "The column Y6 has 106 outliers present!"  
## [1] "The column Y7 has 2104 outliers present!"  
## [1] "The column Y8 has 159 outliers present!"  
## [1] "The column Y9 has 45 outliers present!"  
## [1] "The column Y10 has 126 outliers present!"  
## [1] "The column Y11 has 165 outliers present!"  
## [1] "The column Y12 has 160 outliers present!"  
## [1] "The column Y13 has 20 outliers present!"  
## [1] "The column Y14 has 14 outliers present!"  
## [1] "The column Y15 has 101 outliers present!"  
## [1] "The column Y16 has 522 outliers present!"  
## [1] "The column Y17 has 432 outliers present!"
```

```

## [1] "The column Y18 has 616 outliers present!"
## [1] "The column Y19 has 397 outliers present!"
## [1] "The column Y20 has 535 outliers present!"
## [1] "The column Y21 has 333 outliers present!"
## [1] "The column Y22 has 37 outliers present!"
## [1] "The column Y23 has 267 outliers present!"
## [1] "The column Y24 has 190 outliers present!"
## [1] "The column Y25 has 305 outliers present!"
## [1] "The column Y26 has 408 outliers present!"
## [1] "The column Y27 has 29 outliers present!"
## [1] "The column Y28 has 330 outliers present!"
## [1] "The column Y29 has 157 outliers present!"
## [1] "The column Y30 has 356 outliers present!"
## [1] "The column Y31 has 427 outliers present!"
## [1] "The column Y32 has 430 outliers present!"
## [1] "The column Y33 has 845 outliers present!"
## [1] "The column Y34 has 34 outliers present!"
## [1] "The column Y35 has 392 outliers present!"
## [1] "The column Y36 has 8 outliers present!"
## [1] "The column Y37 has 100 outliers present!"
## [1] "The column Y38 has 106 outliers present!"
## [1] "The column Y39 has 351 outliers present!"
## [1] "The column Y40 has 106 outliers present!"
## [1] "The column Y41 has 186 outliers present!"
## [1] "The column Y42 has 210 outliers present!"
## [1] "The column Y43 has 34 outliers present!"
## [1] "The column Y44 has 17 outliers present!"
## [1] "The column Y45 has 77 outliers present!"
## [1] "The column Y46 has 87 outliers present!"
## [1] "The column Y47 has 304 outliers present!"
## [1] "The column Y48 has 868 outliers present!"
## [1] "The column Y49 has 608 outliers present!"
## [1] "The column Power1 has 1454 outliers present!"
## [1] "The column Power2 has 182 outliers present!"
## [1] "The column Power3 has 896 outliers present!"
## [1] "The column Power4 has 300 outliers present!"
## [1] "The column Power31 has 7 outliers present!"
## [1] "The column Power32 has 5 outliers present!"
## [1] "The column Power34 has 23 outliers present!"
## [1] "The column Power35 has 4 outliers present!"
## [1] "The column Power37 has 3 outliers present!"
## [1] "The column Power38 has 44 outliers present!"
## [1] "The column Power39 has 17 outliers present!"
## [1] "The column Power40 has 7 outliers present!"
## [1] "The column Power41 has 13 outliers present!"
## [1] "The column Power42 has 179 outliers present!"
## [1] "The column Power43 has 664 outliers present!"
## [1] "The column Power44 has 1469 outliers present!"
## [1] "The column Power45 has 706 outliers present!"
## [1] "The column Power46 has 1083 outliers present!"
## [1] "The column Power47 has 619 outliers present!"
## [1] "The column Power48 has 895 outliers present!"
## [1] "The column Power49 has 608 outliers present!"
## [1] "The column qW has 57 outliers present!"

```

```
## [1] "The column Total_Power has 67 outliers present!"
```

After calculating the columns containing outliers, every column consist of so many outliers.

Question 2.2 subpart Removing outliers from the columns using z score.

```
energy.no.df <- energy.df

# Get the column names from energy.df
columns <- colnames(energy.df)
outliers <- numeric(0)

for (col in columns) {
  column_data <- as.numeric(energy.df[[col]])
  z_val <- outlier(column_data)

  # Identify rows with outliers
  outlier_indices <- which(abs(z_val) > 3)
  outliers <- c(outliers, outlier_indices)
}

outliers <- unique(outliers)
energy.no.df <- energy.no.df[-outliers,]

#summary(energy.no.df)

#print(energy.df)
#print(energy.no.df)
```

Question 2.3 Using Shapiro wilk test to check if data energy.no.df is normalized or not. Check_normality function performs the Shapiro-Wilk test for checking normality of a given column in a dataset. It accepts parameters such as the column data, an optional sample_size parameter to test a subset of the data, and the significance level (alpha). Looping over the columns and checking normality to find out the columns that are not reasonably normal even after calculating z score.

```
# Function to check normality using Shapiro-Wilk test
check_normality <- function(column, sample_size = NULL, alpha = 0.05) {
  if (is.null(sample_size)) {
    # If sample_size is not provided, test the entire column
    shapiro_test <- shapiro.test(column)
  } else {
    # If sample_size is provided, create a random subset and test it
    sample_data <- sample(column, size = sample_size)
    shapiro_test <- shapiro.test(sample_data)
  }

  if (shapiro_test$p.value > alpha) {
    return(TRUE) # The data is reasonably normal
  } else {
    return(FALSE) # The data is not reasonably normal
  }
}

# Looping over the columns and checking normality in columns if they are reasonably normal or not
```

```

for (column in colnames(energy.no.df)) {
  is_normal <- check_normality(energy.no.df[, column], sample_size = 5000)

  if (!is_normal) {
    print(paste("The column", column, "is not reasonably normal."))
  }
}

```

```

## [1] "The column X1 is not reasonably normal."
## [1] "The column Y1 is not reasonably normal."
## [1] "The column X2 is not reasonably normal."
## [1] "The column Y2 is not reasonably normal."
## [1] "The column X3 is not reasonably normal."
## [1] "The column Y3 is not reasonably normal."
## [1] "The column X4 is not reasonably normal."
## [1] "The column Y4 is not reasonably normal."
## [1] "The column X5 is not reasonably normal."
## [1] "The column Y5 is not reasonably normal."
## [1] "The column X6 is not reasonably normal."
## [1] "The column Y6 is not reasonably normal."
## [1] "The column X7 is not reasonably normal."
## [1] "The column Y7 is not reasonably normal."
## [1] "The column X8 is not reasonably normal."
## [1] "The column Y8 is not reasonably normal."
## [1] "The column X9 is not reasonably normal."
## [1] "The column Y9 is not reasonably normal."
## [1] "The column X10 is not reasonably normal."
## [1] "The column Y10 is not reasonably normal."
## [1] "The column X11 is not reasonably normal."
## [1] "The column Y11 is not reasonably normal."
## [1] "The column X12 is not reasonably normal."
## [1] "The column Y12 is not reasonably normal."
## [1] "The column X13 is not reasonably normal."
## [1] "The column Y13 is not reasonably normal."
## [1] "The column X14 is not reasonably normal."
## [1] "The column Y14 is not reasonably normal."
## [1] "The column X15 is not reasonably normal."
## [1] "The column Y15 is not reasonably normal."
## [1] "The column X16 is not reasonably normal."
## [1] "The column Y16 is not reasonably normal."
## [1] "The column X17 is not reasonably normal."
## [1] "The column Y17 is not reasonably normal."
## [1] "The column X18 is not reasonably normal."
## [1] "The column Y18 is not reasonably normal."
## [1] "The column X19 is not reasonably normal."
## [1] "The column Y19 is not reasonably normal."
## [1] "The column X20 is not reasonably normal."
## [1] "The column Y20 is not reasonably normal."
## [1] "The column X21 is not reasonably normal."
## [1] "The column Y21 is not reasonably normal."
## [1] "The column X22 is not reasonably normal."
## [1] "The column Y22 is not reasonably normal."

```

[illegible]


```

## [1] "The column Power1 is not reasonably normal."
## [1] "The column Power2 is not reasonably normal."
## [1] "The column Power3 is not reasonably normal."
## [1] "The column Power4 is not reasonably normal."
## [1] "The column Power5 is not reasonably normal."
## [1] "The column Power6 is not reasonably normal."
## [1] "The column Power7 is not reasonably normal."
## [1] "The column Power8 is not reasonably normal."
## [1] "The column Power9 is not reasonably normal."
## [1] "The column Power10 is not reasonably normal."
## [1] "The column Power11 is not reasonably normal."
## [1] "The column Power12 is not reasonably normal."
## [1] "The column Power13 is not reasonably normal."
## [1] "The column Power14 is not reasonably normal."
## [1] "The column Power15 is not reasonably normal."
## [1] "The column Power16 is not reasonably normal."
## [1] "The column Power17 is not reasonably normal."
## [1] "The column Power18 is not reasonably normal."
## [1] "The column Power19 is not reasonably normal."
## [1] "The column Power20 is not reasonably normal."
## [1] "The column Power21 is not reasonably normal."
## [1] "The column Power22 is not reasonably normal."
## [1] "The column Power23 is not reasonably normal."
## [1] "The column Power24 is not reasonably normal."
## [1] "The column Power25 is not reasonably normal."
## [1] "The column Power26 is not reasonably normal."
## [1] "The column Power27 is not reasonably normal."
## [1] "The column Power28 is not reasonably normal."
## [1] "The column Power29 is not reasonably normal."
## [1] "The column Power30 is not reasonably normal."
## [1] "The column Power31 is not reasonably normal."
## [1] "The column Power32 is not reasonably normal."
## [1] "The column Power33 is not reasonably normal."
## [1] "The column Power34 is not reasonably normal."
## [1] "The column Power35 is not reasonably normal."
## [1] "The column Power36 is not reasonably normal."
## [1] "The column Power37 is not reasonably normal."
## [1] "The column Power38 is not reasonably normal."
## [1] "The column Power39 is not reasonably normal."
## [1] "The column Power40 is not reasonably normal."
## [1] "The column Power41 is not reasonably normal."
## [1] "The column Power42 is not reasonably normal."
## [1] "The column Power43 is not reasonably normal."
## [1] "The column Power44 is not reasonably normal."
## [1] "The column Power45 is not reasonably normal."
## [1] "The column Power46 is not reasonably normal."
## [1] "The column Power47 is not reasonably normal."
## [1] "The column Power48 is not reasonably normal."
## [1] "The column Power49 is not reasonably normal."
## [1] "The column qW is not reasonably normal."
## [1] "The column Total_Power is not reasonably normal."

```

Ques 2.4 subpart # Identifying features that are not normally distributed and attempting to normalize them through a log, inverse, or square-root transform into a new data set, energy.tx which should contain those

features from the original data set that were normally distributed and those features that can be normalized through a transform. Therefore Performing a log, inverse, or square-root transform

```
cols <- colnames(energy.no.df)

energy.tx_log <- data.frame(matrix(NA, nrow = nrow(energy.no.df), ncol = length(cols)))
energy.tx_log <- as.data.frame(lapply(energy.no.df, log))

sample_subset1 <- energy.tx_log[sample(nrow(energy.no.df), 5000),]
cols <- colnames(sample_subset1)

for (col in cols){
  shap <- shapiro.test(sample_subset1[, col])
  val <- shap$p.value
  if( !is.na(val) && !is.na(val) && val > 0.05){
    print(paste0("The column", col, "follows normal distribution"))
  }
}
#print(energy.tx_log)
```

Since columns are not reasonably normal even after running the shapiro wilk test so running square root transform. Extremely low values in energy_tx.log, such as “-Inf,” can significantly influence the regression model’s coefficients and predictions which can result in distortion of the model’s fitting process and affect its ability to generalize to new data. Hence trying square root transform.

Ques2.4 subpart Performing a square root transform

```
cols <- colnames(energy.no.df)

energy.tx_sqrt <- data.frame(matrix(NA, nrow = nrow(energy.no.df), ncol = length(cols)))
energy.tx_sqrt <- as.data.frame(lapply(energy.no.df, sqrt))

sample_subset2 <- energy.tx_sqrt[sample(nrow(energy.no.df), 5000),]
cols <- colnames(sample_subset2)

for (col in cols){
  shap <- shapiro.test(sample_subset2[, col])
  val <- shap$p.value
  if( !is.na(val) && !is.na(val) && val > 0.05){
    print(paste0("The column", col, "follows normal distribution"))
  }
}

energy.tx <- energy.tx_sqrt
#print(energy.tx)
```

Even after performing square root transform, the data is not reasonably normal using shapiro wilk test. Hence, moving forward with the inverse transform. Since the dataset is heteroscedastic, using a square root transformation on variables like X5, Y5, X6, Y6, X7, and Y7 might be beneficial.

Ques 2.4 subpart Performing an inverse transform

```

cols <- colnames(energy.no.df)

# Perform square root transformation
energy.tx_in<- data.frame(matrix(NA, nrow = nrow(energy.no.df), ncol = length(cols)))
energy.tx_in <- as.data.frame(lapply(energy.no.df, sqrt))

# Create a sample subset
sample_subset3 <- energy.tx_in[sample(nrow(energy.no.df), 5000),]
cols <- colnames(sample_subset3)

# Loop for square root transformed data
for (col in cols){
  shap <- shapiro.test(sample_subset3[, col])
  val <- shap$p.value
  if (!is.na(val) && val > 0.05){
    print(paste0("The column ", col, " follows normal distribution"))
  }
}

# Perform inverse transformation
energy.tx_inverse <- as.data.frame(lapply(energy.tx_sqrt, function(x) x^2))

# Print the inverse-transformed data
#print(energy.tx_inverse)

```

Even after performing inverse transform, the data is not reasonably normal using shapiro wilk test. Hence, Out of the three transforms , going ahead with square root transform.

Question 2.5

Calculating correlation to the response variable (Total_Power) for energy.no.df. qW and Total Power exhibit a correlation above 0.6 to the response variable

```

#summary(energy.tx)

# Assuming 'energy.no.df' is your DataFrame
# Replace 'your_feature_column' with the actual column names of your features
correlations <- cor(energy.no.df)
correlations_to_response <- correlations['Total_Power', ]

# Features with correlation above 0.6 to the response variable
highly_correlated_features <- names(correlations_to_response[correlations_to_response > 0.6])

cat("Correlations to the response variable (Total_Power):\n")

## Correlations to the response variable (Total_Power):

print(correlations_to_response)

```

```
##           X1           Y1           X2           Y2           X3           Y3
```

```
## 0.444169510 -0.126723600 0.254349845 0.091383675 0.045585229 0.296759338
##          X4          Y4          X5          Y5          X6          Y6
## -0.051188489 0.431107564 0.332301312 -0.168977741 0.233586739 -0.141023492
##          X7          Y7          X8          Y8          X9          Y9
## 0.105528606 -0.124928228 0.372760218 -0.204493324 0.321377373 -0.174635988
##          X10         Y10         X11         Y11         X12         Y12
## 0.259815602 -0.155444716 0.178568060 -0.090989308 0.075217732 -0.040650583
##          X13         Y13         X14         Y14         X15         Y15
## 0.066316404 -0.113465189 -0.044225396 -0.031439487 0.236114193 -0.170197568
##          X16         Y16         X17         Y17         X18         Y18
## 0.139097788 -0.067683359 0.291897476 -0.210205340 0.203888341 -0.111640309
##          X19         Y19         X20         Y20         X21         Y21
## 0.045802844 -0.052920403 -0.089675890 -0.007309950 -0.100745069 -0.010827549
##          X22         Y22         X23         Y23         X24         Y24
## 0.135204013 -0.075691402 0.062965292 -0.011235623 -0.066374208 0.084858348
##          X25         Y25         X26         Y26         X27         Y27
## 0.079060234 -0.035874521 -0.035645318 0.048912757 -0.133554694 0.132926897
##          X28         Y28         X29         Y29         X30         Y30
## -0.199344784 0.193646519 0.125087499 -0.138590404 0.023190439 -0.028172255
##          X31         Y31         X32         Y32         X33         Y33
## -0.132346523 0.010727640 -0.249008794 0.100069951 -0.021878353 -0.087085957
##          X34         Y34         X35         Y35         X36         Y36
## -0.124107352 -0.045301902 -0.212665411 -0.006531677 0.085980003 -0.127372479
##          X37         Y37         X38         Y38         X39         Y39
## 0.110216952 -0.201610494 0.006864614 -0.159121375 -0.118908700 -0.122651750
##          X40         Y40         X41         Y41         X42         Y42
## -0.273819782 0.010736497 -0.265279805 -0.174623273 -0.283063129 -0.114025575
##          X43         Y43         X44         Y44         X45         Y45
## -0.078074150 -0.203848393 -0.148763961 -0.177594277 0.152398915 -0.488236145
##          X46         Y46         X47         Y47         X48         Y48
## 0.047867391 -0.513193297 -0.074471647 -0.390159058 -0.257712101 -0.299105405
##          X49         Y49         Power1        Power2        Power3        Power4
## -0.415131672 -0.083006128 0.455718127 0.470580112 0.183697543 -0.008890707
##          Power5        Power6        Power7        Power8        Power9        Power10
## 0.247484013 0.233927362 0.065719457 0.453841628 0.291144253 0.322483471
##          Power11       Power12       Power13       Power14       Power15       Power16
## 0.320535998 0.263819417 0.052570834 0.008784530 0.338461982 0.281569772
##          Power17       Power18       Power19       Power20       Power21       Power22
## 0.359653866 0.375110903 0.267884708 0.074976858 0.006882265 0.197607765
##          Power23       Power24       Power25       Power26       Power27       Power28
## 0.204733353 0.107648702 0.233716557 0.272236974 0.239441875 0.077970073
##          Power29       Power30       Power31       Power32       Power33       Power34
## 0.015769483 0.160361928 0.205630378 0.180112587 0.269658780 0.333331275
##          Power35       Power36       Power37       Power38       Power39       Power40
## 0.208200384 0.311693244 0.108179858 0.379152199 0.467239320 0.454998056
##          Power41       Power42       Power43       Power44       Power45       Power46
## 0.107596501 0.296950603 0.332964325 0.339832928 0.328705974 0.334490809
##          Power47       Power48       Power49       qW      Total_Power
## 0.405819321 0.190514362 -0.134286117 0.993193574 1.000000000
```

```
cat("\nFeatures with correlation above 0.6 to the response variable:\n")
```

```
##
## Features with correlation above 0.6 to the response variable:
```

```
print(highly_correlated_features)
```

```
## [1] "qW"          "Total_Power"
```

Question 2.6

Now we will be splitting all the 3 data sets we created above into training and validating subsets. Splitting energy.no.df, energy.df, and energy.tx into 70%/30% subsets. Retaining 30% for testing using random sampling without replacement.

```
set.seed(123)

# Split ratio = 70%
split.ratio <- 0.7

# Splitting energy.df original data into training and testing data
sample_rows <- sample(nrow(energy.df))
train <- floor(split.ratio * nrow(energy.df))
energy.training <- energy.df[sample_rows[1:train], ]
energy.testing <- energy.df[sample_rows[(train + 1):nrow(energy.df)], ]

# Splitting the energy.no.df into training and testing data
sampe_rows_no <- sample(nrow(energy.no.df))
train_no <- floor(split.ratio*nrow(energy.no.df))
energy.no.training <- energy.no.df[sample_rows[1:train_no], ]
energy.no.testing <- energy.no.df[sampe_rows_no[(train_no + 1): nrow(energy.no.df)], ]

# Splitting the energy.tx into training and testing data
sampe_rows_tx <- sample(nrow(energy.tx))
train_tx <- floor(split.ratio*nrow(energy.tx))
energy.tx.training <- energy.tx[sample_rows[1:train_tx], ]
energy.tx.testing <- energy.tx[sampe_rows_tx[(train_tx + 1): nrow(energy.tx)], ]
```

Question 2.6 subpart and 2.7 and 2.8

Performing backward elimination based on p-value for predicting Total_Power. Building three multiple regression models for energy.training, energy.no.training, and energy.tx.training. Calling the data sets, energy.training and energy.testing, energy.no.training and energy.no.testing, and energy.tx.training and energy.tx.testing for analyzing the three models. Calculating RMSE, adjusted R square

```
backward_elimination <- function(dataset) {
  original_dataset <- dataset
  model <- lm(Total_Power ~ ., data = dataset)

  while (TRUE) {
    energy_model <- summary(model)
    p_values <- energy_model$coefficients[, "Pr(>|t|)"]
    max_p_value <- max(p_values)
```

```

# If the largest p-value is greater than 0.05, remove the corresponding variable
if (max_p_value > 0.05) {
  remove_variable <- names(p_values[p_values == max_p_value])

  # Remove the variable from the dataset having max p values
  dataset <- dataset[, !colnames(dataset) %in% remove_variable, drop = FALSE]

  # Update the model with the modified dataset
  model <- lm(Total_Power ~ ., data = dataset)
} else {
  # If no p-value is above 0.05, break the loop
  break
}
}
residuals <- residuals(model)
rse <- sd(residuals)
rmse <- sqrt(mean(residuals^2))
return(list(model = model, dataset = original_dataset, rse = rse, rmse = rmse))
}

testing_dataset <- energy.testing

# Call the backward_elimination function for energy.training dataset
result_energy_training <- backward_elimination(energy.training)
cat("Summary of Model for energy.training:\n")

```

```
## Summary of Model for energy.training:
```

```
print(summary(result_energy_training$model))
```

```
##
## Call:
## lm(formula = Total_Power ~ ., data = dataset)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2874.09  -101.14    12.32   131.34  2892.78
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.305e+03  2.036e+02  26.056 < 2e-16 ***
## X1           -6.472e-02  1.757e-02  -3.684 0.000230 ***
## Y1           -6.204e-01  7.232e-02  -8.578 < 2e-16 ***
## X2            2.595e-01  1.957e-02  13.263 < 2e-16 ***
## Y2            5.993e-01  4.659e-02  12.865 < 2e-16 ***
## Y3            7.237e-01  7.159e-02  10.108 < 2e-16 ***
## X4           -1.735e-01  1.482e-02 -11.706 < 2e-16 ***
## X5           -5.176e-02  1.591e-02  -3.254 0.001139 **
## Y5           -1.389e+00  7.107e-02 -19.542 < 2e-16 ***
## X6            1.282e-01  1.794e-02   7.147 9.11e-13 ***

```

## Y6	-2.523e+00	9.214e-02	-27.388	< 2e-16	***
## X7	-1.468e-01	1.674e-02	-8.771	< 2e-16	***
## Y7	2.323e+00	1.043e-01	22.279	< 2e-16	***
## X8	8.988e-02	1.514e-02	5.937	2.94e-09	***
## Y8	7.679e-01	5.778e-02	13.289	< 2e-16	***
## X9	8.353e-02	1.352e-02	6.178	6.58e-10	***
## Y9	2.170e-01	4.975e-02	4.363	1.29e-05	***
## X10	1.927e-01	1.505e-02	12.804	< 2e-16	***
## Y10	1.714e-01	4.823e-02	3.553	0.000381	***
## X11	7.531e-02	1.506e-02	5.001	5.74e-07	***
## Y11	3.032e-01	5.349e-02	5.668	1.46e-08	***
## Y12	-9.807e-01	5.503e-02	-17.822	< 2e-16	***
## X13	-3.622e-02	1.430e-02	-2.532	0.011342	*
## Y13	3.549e-01	6.231e-02	5.696	1.24e-08	***
## X14	6.461e-02	1.535e-02	4.210	2.56e-05	***
## Y14	2.592e-01	6.628e-02	3.912	9.19e-05	***
## X15	8.257e-02	1.428e-02	5.782	7.48e-09	***
## Y15	2.619e-01	4.906e-02	5.338	9.50e-08	***
## Y16	-6.802e-01	4.378e-02	-15.539	< 2e-16	***
## Y17	8.865e-01	4.589e-02	19.316	< 2e-16	***
## X18	3.321e-02	1.414e-02	2.349	0.018837	*
## X19	-4.425e-02	1.590e-02	-2.783	0.005394	**
## Y19	-5.346e-01	5.096e-02	-10.490	< 2e-16	***
## X20	4.165e-02	1.384e-02	3.010	0.002619	**
## Y20	1.105e-01	4.271e-02	2.587	0.009684	**
## Y21	-1.738e-01	4.185e-02	-4.152	3.31e-05	***
## X22	-6.144e-02	1.285e-02	-4.782	1.74e-06	***
## Y22	5.117e-01	5.746e-02	8.906	< 2e-16	***
## X23	-5.545e-02	1.260e-02	-4.401	1.08e-05	***
## X24	5.962e-02	1.303e-02	4.576	4.77e-06	***
## Y24	-4.770e-01	4.857e-02	-9.821	< 2e-16	***
## X25	-7.235e-02	1.312e-02	-5.514	3.55e-08	***
## Y25	3.869e-01	4.441e-02	8.713	< 2e-16	***
## X26	-7.905e-02	1.356e-02	-5.829	5.64e-09	***
## X27	-6.750e-02	1.323e-02	-5.100	3.42e-07	***
## Y27	-5.805e-01	5.138e-02	-11.298	< 2e-16	***
## Y28	1.868e-01	5.054e-02	3.697	0.000219	***
## X29	-5.712e-02	1.193e-02	-4.790	1.68e-06	***
## X30	-5.481e-02	1.319e-02	-4.157	3.24e-05	***
## Y30	-1.960e-01	6.079e-02	-3.224	0.001267	**
## X31	1.309e-01	1.382e-02	9.473	< 2e-16	***
## Y31	3.839e-01	6.065e-02	6.330	2.49e-10	***
## X32	-6.837e-02	1.333e-02	-5.130	2.92e-07	***
## Y32	-5.552e-01	6.560e-02	-8.464	< 2e-16	***
## Y33	-6.505e-01	4.708e-02	-13.817	< 2e-16	***
## X34	8.590e-02	1.335e-02	6.435	1.26e-10	***
## Y34	6.590e-01	6.361e-02	10.361	< 2e-16	***
## X35	6.414e-02	1.325e-02	4.840	1.30e-06	***
## Y35	-1.476e-01	5.015e-02	-2.942	0.003263	**
## X36	1.124e-01	1.291e-02	8.705	< 2e-16	***
## Y36	1.065e+00	6.385e-02	16.679	< 2e-16	***
## X37	-6.815e-02	1.238e-02	-5.507	3.69e-08	***
## Y37	-1.045e-01	5.049e-02	-2.069	0.038515	*
## X38	6.957e-02	1.258e-02	5.529	3.24e-08	***

## Y38	1.106e+00	5.536e-02	19.979	< 2e-16	***
## X39	-1.614e-01	1.308e-02	-12.340	< 2e-16	***
## Y39	-4.261e-01	5.504e-02	-7.741	1.02e-14	***
## X40	1.043e-01	1.267e-02	8.236	< 2e-16	***
## Y40	-1.347e-01	5.577e-02	-2.415	0.015737	*
## X41	5.718e-02	1.182e-02	4.838	1.32e-06	***
## Y41	-2.237e-01	5.974e-02	-3.746	0.000180	***
## X42	9.230e-02	1.254e-02	7.359	1.91e-13	***
## Y42	-8.483e-01	5.052e-02	-16.793	< 2e-16	***
## X43	3.332e-02	1.363e-02	2.444	0.014513	*
## Y43	-2.228e+00	8.191e-02	-27.199	< 2e-16	***
## X44	-2.791e-01	1.366e-02	-20.426	< 2e-16	***
## Y44	3.054e+00	7.702e-02	39.644	< 2e-16	***
## X45	-3.257e-02	1.220e-02	-2.670	0.007585	**
## Y45	4.253e-01	7.550e-02	5.634	1.78e-08	***
## X46	-9.994e-02	1.099e-02	-9.090	< 2e-16	***
## Y46	5.942e-01	7.305e-02	8.134	4.36e-16	***
## X47	-1.581e-01	1.047e-02	-15.103	< 2e-16	***
## X48	2.398e-01	1.149e-02	20.864	< 2e-16	***
## Y48	-1.810e+00	7.325e-02	-24.711	< 2e-16	***
## X49	-5.159e-01	1.080e-02	-47.781	< 2e-16	***
## Y49	1.438e+00	2.773e-02	51.835	< 2e-16	***
## Power1	1.004e+00	4.186e-04	2397.255	< 2e-16	***
## Power2	9.942e-01	4.138e-04	2402.497	< 2e-16	***
## Power3	9.982e-01	2.772e-04	3600.612	< 2e-16	***
## Power4	1.003e+00	3.284e-04	3054.820	< 2e-16	***
## Power5	1.002e+00	3.366e-04	2976.156	< 2e-16	***
## Power6	9.900e-01	3.656e-04	2707.438	< 2e-16	***
## Power7	1.002e+00	3.364e-04	2979.106	< 2e-16	***
## Power8	9.960e-01	3.128e-04	3184.627	< 2e-16	***
## Power9	9.981e-01	3.063e-04	3259.023	< 2e-16	***
## Power10	9.954e-01	3.421e-04	2909.723	< 2e-16	***
## Power11	9.968e-01	3.442e-04	2895.750	< 2e-16	***
## Power12	9.977e-01	2.478e-04	4025.968	< 2e-16	***
## Power13	1.001e+00	3.068e-04	3263.472	< 2e-16	***
## Power14	9.986e-01	3.367e-04	2966.139	< 2e-16	***
## Power15	9.973e-01	3.237e-04	3080.586	< 2e-16	***
## Power16	9.980e-01	2.452e-04	4070.739	< 2e-16	***
## Power17	9.992e-01	2.822e-04	3540.240	< 2e-16	***
## Power18	9.996e-01	3.736e-04	2675.702	< 2e-16	***
## Power19	9.973e-01	3.533e-04	2823.079	< 2e-16	***
## Power20	9.986e-01	3.048e-04	3275.845	< 2e-16	***
## Power21	9.959e-01	2.501e-04	3981.503	< 2e-16	***
## Power22	1.001e+00	3.186e-04	3140.404	< 2e-16	***
## Power23	1.001e+00	3.259e-04	3072.688	< 2e-16	***
## Power24	9.985e-01	3.049e-04	3274.861	< 2e-16	***
## Power25	9.987e-01	3.334e-04	2995.215	< 2e-16	***
## Power26	1.000e+00	3.658e-04	2733.488	< 2e-16	***
## Power27	9.979e-01	3.513e-04	2840.945	< 2e-16	***
## Power28	9.973e-01	2.888e-04	3453.800	< 2e-16	***
## Power29	1.001e+00	3.220e-04	3109.399	< 2e-16	***
## Power30	1.001e+00	3.468e-04	2887.417	< 2e-16	***
## Power31	9.957e-01	3.680e-04	2705.941	< 2e-16	***
## Power32	9.994e-01	3.304e-04	3024.338	< 2e-16	***


```
## Power33      9.966e-01  2.962e-04 3364.647 < 2e-16 ***
## Power34      9.961e-01  3.616e-04 2754.676 < 2e-16 ***
## Power35      9.998e-01  3.401e-04 2939.777 < 2e-16 ***
## Power36      9.964e-01  3.165e-04 3147.896 < 2e-16 ***
## Power37      9.977e-01  3.026e-04 3296.809 < 2e-16 ***
## Power38      9.949e-01  3.484e-04 2855.353 < 2e-16 ***
## Power39      9.964e-01  3.650e-04 2729.800 < 2e-16 ***
## Power40      9.959e-01  3.453e-04 2884.186 < 2e-16 ***
## Power41      9.957e-01  3.297e-04 3020.149 < 2e-16 ***
## Power42      9.933e-01  3.841e-04 2586.116 < 2e-16 ***
## Power43      9.962e-01  3.832e-04 2599.931 < 2e-16 ***
## Power44      9.904e-01  3.806e-04 2602.424 < 2e-16 ***
## Power45      9.913e-01  4.950e-04 2002.664 < 2e-16 ***
## Power46      9.942e-01  5.378e-04 1848.783 < 2e-16 ***
## Power47      9.908e-01  6.434e-04 1539.879 < 2e-16 ***
## Power48      9.983e-01  8.431e-04 1184.091 < 2e-16 ***
## Power49      1.004e+00  6.261e-04 1602.942 < 2e-16 ***
## qW           3.989e+03  5.945e+02    6.709 1.99e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 264.1 on 25094 degrees of freedom
## Multiple R-squared:  1, Adjusted R-squared:  1
## F-statistic: 4.022e+07 on 135 and 25094 DF, p-value: < 2.2e-16
```

```
# Make predictions on testing data energy.training
predictions_energy.training <- predict(result_energy_training$model, new_data = energy.testing)

# Calculate RMSE
rmse_energy.training <- sqrt(mean((predictions_energy.training - testing_dataset$Total_Power)^2))
```

```
## Warning in predictions_energy.training - testing_dataset$Total_Power: longer
## object length is not a multiple of shorter object length
```

```
# Print the adjusted R-squared and RMSE
cat("RMSE for energy.training dataset:", rmse_energy.training, "\n")
```

```
## RMSE for energy.training dataset: 172661.2
```

```
# Access the modified dataset after elimination
#modified_energy_training <- result_energy_training$dataset

result_energy_no_training <- backward_elimination(energy.no.training)
cat("Summary of Model for energy.no.training: \n")
```

```
## Summary of Model for energy.no.training:
```

```
print(summary(result_energy_no_training$model))
```

```
##
## Call:
```

```
## lm(formula = Total_Power ~ ., data = dataset)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2610.51  -107.43    15.53   130.50  2763.14
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.354e+03  2.206e+02  24.270 < 2e-16 ***
## Y1          -2.499e-01  7.405e-02  -3.374 0.000741 ***
## X2           2.544e-01  1.811e-02  14.047 < 2e-16 ***
## Y2           4.690e-01  4.744e-02   9.886 < 2e-16 ***
## Y3           9.456e-01  8.021e-02  11.789 < 2e-16 ***
## X4          -2.137e-01  1.670e-02 -12.793 < 2e-16 ***
## Y4          -3.403e-01  7.946e-02  -4.282 1.86e-05 ***
## Y5          -1.088e+00  7.130e-02 -15.257 < 2e-16 ***
## X6           1.104e-01  1.935e-02   5.704 1.19e-08 ***
## Y6          -2.871e+00  9.769e-02 -29.385 < 2e-16 ***
## X7          -1.708e-01  1.979e-02  -8.633 < 2e-16 ***
## Y7           2.696e+00  1.062e-01  25.392 < 2e-16 ***
## X8           1.301e-01  1.811e-02   7.182 7.10e-13 ***
## Y8           5.774e-01  5.611e-02  10.290 < 2e-16 ***
## X9           9.205e-02  1.640e-02   5.613 2.01e-08 ***
## Y9           4.043e-01  5.600e-02   7.220 5.37e-13 ***
## X10          1.830e-01  1.841e-02   9.943 < 2e-16 ***
## Y10          2.524e-01  4.952e-02   5.096 3.49e-07 ***
## X11          6.287e-02  1.995e-02   3.151 0.001631 **
## Y11          1.653e-01  5.914e-02   2.795 0.005192 **
## X12          3.499e-02  1.742e-02   2.009 0.044562 *
## Y12         -1.140e+00  6.002e-02 -19.002 < 2e-16 ***
## Y13          4.763e-01  6.597e-02   7.219 5.39e-13 ***
## X14          5.605e-02  1.733e-02   3.235 0.001220 **
## Y14          1.466e-01  6.775e-02   2.163 0.030527 *
## X15          9.393e-02  1.661e-02   5.656 1.57e-08 ***
## Y15          2.512e-01  5.004e-02   5.021 5.19e-07 ***
## Y16         -6.296e-01  4.504e-02 -13.977 < 2e-16 ***
## X17          4.335e-02  1.551e-02   2.794 0.005206 **
## Y17          1.131e+00  5.054e-02  22.371 < 2e-16 ***
## Y18         -2.087e-01  5.202e-02  -4.012 6.04e-05 ***
## Y19         -5.890e-01  5.310e-02 -11.091 < 2e-16 ***
## X20          3.786e-02  1.395e-02   2.713 0.006668 **
## X21          3.920e-02  1.500e-02   2.613 0.008979 **
## Y21         -1.906e-01  4.555e-02  -4.184 2.88e-05 ***
## X22         -9.620e-02  1.600e-02  -6.014 1.84e-09 ***
## Y22          4.835e-01  6.342e-02   7.624 2.56e-14 ***
## X23         -7.197e-02  1.486e-02  -4.843 1.29e-06 ***
## X24          5.707e-02  1.484e-02   3.845 0.000121 ***
## Y24         -5.064e-01  5.134e-02  -9.863 < 2e-16 ***
## X25         -5.451e-02  1.524e-02  -3.577 0.000348 ***
## Y25          2.497e-01  5.033e-02   4.962 7.03e-07 ***
## X26         -8.481e-02  1.621e-02  -5.231 1.70e-07 ***
## Y26          2.129e-01  5.925e-02   3.593 0.000327 ***
## X27         -5.488e-02  1.579e-02  -3.475 0.000511 ***
## Y27         -6.899e-01  5.313e-02 -12.984 < 2e-16 ***
```

## X28	-3.098e-02	1.482e-02	-2.091	0.036537	*
## Y28	2.513e-01	5.702e-02	4.406	1.06e-05	***
## X29	-3.202e-02	1.369e-02	-2.339	0.019328	*
## X30	-9.417e-02	1.425e-02	-6.606	4.03e-11	***
## X31	1.317e-01	1.416e-02	9.298	< 2e-16	***
## X32	-1.015e-01	1.435e-02	-7.072	1.57e-12	***
## Y32	-4.328e-01	5.367e-02	-8.063	7.83e-16	***
## Y33	-6.895e-01	5.016e-02	-13.746	< 2e-16	***
## X34	8.950e-02	1.479e-02	6.051	1.46e-09	***
## Y34	6.993e-01	6.539e-02	10.695	< 2e-16	***
## X35	6.541e-02	1.418e-02	4.613	3.98e-06	***
## X36	1.114e-01	1.391e-02	8.004	1.26e-15	***
## Y36	1.181e+00	6.534e-02	18.078	< 2e-16	***
## X37	-7.861e-02	1.350e-02	-5.821	5.92e-09	***
## Y37	-2.247e-01	5.378e-02	-4.179	2.94e-05	***
## X38	3.194e-02	1.376e-02	2.321	0.020301	*
## Y38	1.151e+00	5.637e-02	20.425	< 2e-16	***
## X39	-1.778e-01	1.397e-02	-12.728	< 2e-16	***
## Y39	-5.780e-01	6.060e-02	-9.538	< 2e-16	***
## X40	9.707e-02	1.360e-02	7.137	9.80e-13	***
## Y40	-1.364e-01	6.178e-02	-2.208	0.027223	*
## X41	4.967e-02	1.235e-02	4.021	5.82e-05	***
## X42	1.014e-01	1.378e-02	7.357	1.94e-13	***
## Y42	-1.094e+00	5.136e-02	-21.306	< 2e-16	***
## Y43	-2.887e+00	8.094e-02	-35.666	< 2e-16	***
## X44	-2.733e-01	1.425e-02	-19.176	< 2e-16	***
## Y44	3.777e+00	8.361e-02	45.178	< 2e-16	***
## X45	-5.901e-02	1.280e-02	-4.609	4.07e-06	***
## Y45	1.982e-01	7.973e-02	2.486	0.012925	*
## X46	-4.934e-02	1.195e-02	-4.129	3.65e-05	***
## Y46	7.790e-01	7.927e-02	9.827	< 2e-16	***
## X47	-1.869e-01	1.152e-02	-16.222	< 2e-16	***
## X48	2.195e-01	1.214e-02	18.074	< 2e-16	***
## Y48	-1.733e+00	7.359e-02	-23.554	< 2e-16	***
## X49	-4.779e-01	1.166e-02	-40.990	< 2e-16	***
## Y49	1.974e+00	4.051e-02	48.737	< 2e-16	***
## Power1	1.002e+00	3.606e-04	2779.692	< 2e-16	***
## Power2	9.947e-01	4.283e-04	2322.660	< 2e-16	***
## Power3	9.977e-01	2.917e-04	3420.464	< 2e-16	***
## Power4	1.004e+00	3.526e-04	2846.720	< 2e-16	***
## Power5	1.001e+00	2.903e-04	3448.217	< 2e-16	***
## Power6	9.903e-01	4.001e-04	2475.257	< 2e-16	***
## Power7	1.004e+00	3.949e-04	2541.213	< 2e-16	***
## Power8	9.954e-01	3.621e-04	2749.247	< 2e-16	***
## Power9	9.979e-01	3.730e-04	2675.303	< 2e-16	***
## Power10	9.953e-01	4.282e-04	2324.401	< 2e-16	***
## Power11	9.977e-01	4.483e-04	2225.635	< 2e-16	***
## Power12	9.966e-01	3.544e-04	2812.006	< 2e-16	***
## Power13	1.001e+00	2.697e-04	3710.883	< 2e-16	***
## Power14	9.986e-01	3.893e-04	2565.285	< 2e-16	***
## Power15	9.970e-01	3.718e-04	2681.276	< 2e-16	***
## Power16	9.980e-01	2.611e-04	3822.801	< 2e-16	***
## Power17	9.982e-01	3.814e-04	2617.351	< 2e-16	***
## Power18	9.997e-01	3.327e-04	3004.642	< 2e-16	***

```
## Power19      9.965e-01  3.045e-04 3272.827 < 2e-16 ***
## Power20      9.987e-01  3.294e-04 3031.598 < 2e-16 ***
## Power21      9.944e-01  3.631e-04 2739.058 < 2e-16 ***
## Power22      1.001e+00  3.886e-04 2577.157 < 2e-16 ***
## Power23      1.001e+00  3.745e-04 2673.830 < 2e-16 ***
## Power24      9.980e-01  3.519e-04 2835.928 < 2e-16 ***
## Power25      9.984e-01  3.792e-04 2632.700 < 2e-16 ***
## Power26      1.000e+00  4.235e-04 2361.234 < 2e-16 ***
## Power27      9.974e-01  4.224e-04 2361.201 < 2e-16 ***
## Power28      9.978e-01  3.660e-04 2726.488 < 2e-16 ***
## Power29      1.001e+00  3.600e-04 2779.253 < 2e-16 ***
## Power30      1.002e+00  3.774e-04 2654.971 < 2e-16 ***
## Power31      9.954e-01  3.882e-04 2563.958 < 2e-16 ***
## Power32      9.999e-01  3.546e-04 2819.969 < 2e-16 ***
## Power33      9.970e-01  3.191e-04 3124.274 < 2e-16 ***
## Power34      9.958e-01  3.953e-04 2519.433 < 2e-16 ***
## Power35      9.994e-01  3.690e-04 2708.340 < 2e-16 ***
## Power36      9.969e-01  3.364e-04 2963.066 < 2e-16 ***
## Power37      9.976e-01  3.217e-04 3101.215 < 2e-16 ***
## Power38      9.954e-01  3.742e-04 2659.758 < 2e-16 ***
## Power39      9.965e-01  3.900e-04 2555.361 < 2e-16 ***
## Power40      9.965e-01  3.661e-04 2722.196 < 2e-16 ***
## Power41      9.969e-01  3.505e-04 2844.407 < 2e-16 ***
## Power42      9.923e-01  4.183e-04 2372.515 < 2e-16 ***
## Power43      9.976e-01  4.229e-04 2358.995 < 2e-16 ***
## Power44      9.911e-01  4.233e-04 2341.329 < 2e-16 ***
## Power45      9.925e-01  5.243e-04 1892.927 < 2e-16 ***
## Power46      9.945e-01  6.047e-04 1644.568 < 2e-16 ***
## Power47      9.906e-01  7.055e-04 1404.010 < 2e-16 ***
## Power48      9.968e-01  9.322e-04 1069.365 < 2e-16 ***
## Power49      1.000e+00  8.161e-04 1225.444 < 2e-16 ***
## qW           3.671e+03  6.260e+02    5.864 4.58e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 261.7 on 22221 degrees of freedom
## (1404 observations deleted due to missingness)
## Multiple R-squared:      1, Adjusted R-squared:      1
## F-statistic: 3.712e+07 on 131 and 22221 DF, p-value: < 2.2e-16
```

```
testing_noenergy <- energy.no.testing
# Make predictions on testing data
predictions_energy.no.testing <- predict(result_energy_no_training$model, newdata = testing_noenergy)

# Calculate RMSE
rmse_energy.no.training <- sqrt(mean((predictions_energy.no.testing - testing_noenergy$Total_Power)^2))
cat("RMSE for no energy training dataset:", rmse_energy.no.training, "\n")
```

```
## RMSE for no energy training dataset: 256.8011
```

```
result_energy.tx <- backward_elimination(energy.tx.training)
cat("Summary of Model for square root transformed training dataset :\n")
```

```
## Summary of Model for square root transformed training dataset :
```

```
print(summary(result_energy.tx$model))
```

```
##
## Call:
## lm(formula = Total_Power ~ ., data = dataset)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4.2372 -0.3120 -0.0283  0.2917  4.6288
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.034e+02  9.640e-01 107.300 < 2e-16 ***
## X1           -8.705e-03  1.197e-03  -7.275 3.59e-13 ***
## Y1           -3.014e-02  2.181e-03 -13.815 < 2e-16 ***
## Y2            1.632e-02  2.083e-03   7.835 4.89e-15 ***
## X3            1.077e-02  1.648e-03   6.533 6.60e-11 ***
## Y3            4.789e-02  2.215e-03  21.623 < 2e-16 ***
## X4           -7.169e-03  1.332e-03  -5.383 7.38e-08 ***
## Y4            4.871e-02  2.149e-03  22.668 < 2e-16 ***
## X5           -2.156e-02  1.443e-03 -14.945 < 2e-16 ***
## Y5           -4.181e-02  1.911e-03 -21.879 < 2e-16 ***
## Y6            2.051e-02  2.272e-03   9.029 < 2e-16 ***
## X7           -1.116e-02  1.593e-03  -7.006 2.52e-12 ***
## Y7           -5.103e-02  2.766e-03 -18.450 < 2e-16 ***
## X8           -8.464e-03  1.311e-03  -6.454 1.11e-10 ***
## Y8            5.536e-02  2.666e-03  20.764 < 2e-16 ***
## X9            3.864e-03  1.241e-03   3.113 0.001852 **
## Y9           -2.112e-02  2.357e-03  -8.958 < 2e-16 ***
## X10           1.388e-02  1.397e-03   9.932 < 2e-16 ***
## X11           -9.191e-03  1.694e-03  -5.425 5.86e-08 ***
## Y11           3.543e-02  2.951e-03  12.006 < 2e-16 ***
## X12           -1.033e-02  1.452e-03  -7.115 1.15e-12 ***
## Y12           9.894e-03  2.446e-03   4.045 5.24e-05 ***
## X13           8.887e-03  1.473e-03   6.034 1.62e-09 ***
## Y13           -3.569e-02  2.527e-03 -14.124 < 2e-16 ***
## X14           -5.456e-03  1.487e-03  -3.668 0.000245 ***
## Y14           -4.213e-02  2.922e-03 -14.418 < 2e-16 ***
## X15           9.350e-03  1.289e-03   7.253 4.21e-13 ***
## Y15           5.207e-02  4.579e-03  11.370 < 2e-16 ***
## X16           -6.938e-03  1.202e-03  -5.774 7.86e-09 ***
## Y16           6.206e-02  3.849e-03  16.123 < 2e-16 ***
## X17           7.938e-03  1.341e-03   5.921 3.26e-09 ***
## Y17           -5.888e-02  3.467e-03 -16.983 < 2e-16 ***
## Y18           1.367e-02  2.989e-03   4.574 4.81e-06 ***
## X19           3.180e-03  1.417e-03   2.244 0.024810 *
## X20           -6.201e-03  1.251e-03  -4.957 7.21e-07 ***
## Y20           8.651e-03  2.615e-03   3.309 0.000939 ***
## X21           9.126e-03  1.169e-03   7.803 6.30e-15 ***
## Y21           -3.224e-02  2.681e-03 -12.024 < 2e-16 ***
## X22           9.615e-03  1.099e-03   8.746 < 2e-16 ***
## Y22           -3.875e-02  6.124e-03  -6.327 2.55e-10 ***
## X23           4.900e-03  1.070e-03   4.580 4.67e-06 ***
```

## Y23	1.102e-01	6.097e-03	18.079	< 2e-16	***
## Y24	1.591e-02	5.040e-03	3.157	0.001594	**
## X25	9.850e-03	1.181e-03	8.342	< 2e-16	***
## Y25	-2.425e-02	4.604e-03	-5.267	1.40e-07	***
## X26	-6.738e-03	1.234e-03	-5.463	4.74e-08	***
## Y26	-3.584e-02	4.792e-03	-7.480	7.71e-14	***
## X27	5.777e-03	1.203e-03	4.802	1.58e-06	***
## Y27	3.573e-02	4.924e-03	7.255	4.15e-13	***
## X29	1.728e-02	1.117e-03	15.468	< 2e-16	***
## Y29	3.654e-02	5.616e-03	6.506	7.87e-11	***
## X30	2.967e-03	1.130e-03	2.626	0.008639	**
## X31	-1.050e-02	1.174e-03	-8.944	< 2e-16	***
## Y31	-2.212e-02	6.432e-03	-3.439	0.000585	***
## X32	-1.070e-02	9.857e-04	-10.858	< 2e-16	***
## Y33	-3.581e-02	5.933e-03	-6.035	1.61e-09	***
## X34	-3.822e-03	1.182e-03	-3.235	0.001217	**
## Y34	2.952e-02	7.697e-03	3.836	0.000126	***
## X35	-1.421e-02	1.192e-03	-11.921	< 2e-16	***
## Y35	3.028e-02	5.769e-03	5.249	1.54e-07	***
## X36	-1.944e-03	9.499e-04	-2.047	0.040679	*
## X37	-2.466e-03	1.076e-03	-2.292	0.021943	*
## Y37	5.726e-02	7.205e-03	7.947	2.00e-15	***
## Y38	2.340e-02	6.482e-03	3.610	0.000306	***
## X39	-1.312e-02	1.087e-03	-12.073	< 2e-16	***
## Y39	3.028e-02	6.782e-03	4.466	8.03e-06	***
## X40	-1.712e-02	1.061e-03	-16.141	< 2e-16	***
## Y40	-9.083e-02	7.926e-03	-11.459	< 2e-16	***
## X41	-9.463e-03	9.854e-04	-9.603	< 2e-16	***
## Y41	-1.035e-01	7.296e-03	-14.181	< 2e-16	***
## X42	-1.542e-02	1.049e-03	-14.701	< 2e-16	***
## X43	-9.198e-03	1.076e-03	-8.545	< 2e-16	***
## Y43	1.649e-01	1.206e-02	13.670	< 2e-16	***
## X44	-2.833e-03	1.039e-03	-2.726	0.006425	**
## Y44	-3.750e-02	1.179e-02	-3.182	0.001463	**
## X45	-9.963e-03	1.043e-03	-9.550	< 2e-16	***
## Y45	-9.284e-02	1.025e-02	-9.054	< 2e-16	***
## X46	-1.647e-02	9.087e-04	-18.121	< 2e-16	***
## Y46	-1.906e-01	1.091e-02	-17.474	< 2e-16	***
## X47	-1.496e-02	9.351e-04	-16.002	< 2e-16	***
## Y47	-6.827e-02	7.982e-03	-8.552	< 2e-16	***
## X48	-1.068e-02	9.461e-04	-11.288	< 2e-16	***
## Y48	-6.127e-02	1.025e-02	-5.977	2.30e-09	***
## X49	-4.299e-02	9.650e-04	-44.550	< 2e-16	***
## Y49	-4.453e-02	5.014e-03	-8.882	< 2e-16	***
## Power1	1.300e-01	4.589e-04	283.303	< 2e-16	***
## Power2	1.247e-01	4.224e-04	295.290	< 2e-16	***
## Power3	1.244e-01	4.742e-04	262.301	< 2e-16	***
## Power4	1.276e-01	3.998e-04	319.257	< 2e-16	***
## Power5	1.333e-01	3.959e-04	336.678	< 2e-16	***
## Power6	1.275e-01	3.382e-04	376.860	< 2e-16	***
## Power7	1.275e-01	4.789e-04	266.156	< 2e-16	***
## Power8	1.302e-01	4.245e-04	306.616	< 2e-16	***
## Power9	1.300e-01	4.258e-04	305.192	< 2e-16	***
## Power10	1.251e-01	4.884e-04	256.060	< 2e-16	***

```
## Power11      1.319e-01  5.258e-04 250.804 < 2e-16 ***
## Power12      1.280e-01  4.319e-04 296.453 < 2e-16 ***
## Power13      1.248e-01  4.236e-04 294.713 < 2e-16 ***
## Power14      1.280e-01  4.675e-04 273.862 < 2e-16 ***
## Power15      1.259e-01  4.558e-04 276.165 < 2e-16 ***
## Power16      1.284e-01  4.030e-04 318.624 < 2e-16 ***
## Power17      1.223e-01  4.395e-04 278.311 < 2e-16 ***
## Power18      1.291e-01  4.223e-04 305.765 < 2e-16 ***
## Power19      1.242e-01  4.879e-04 254.508 < 2e-16 ***
## Power20      1.276e-01  4.213e-04 302.924 < 2e-16 ***
## Power21      1.228e-01  4.305e-04 285.316 < 2e-16 ***
## Power22      1.266e-01  4.545e-04 278.543 < 2e-16 ***
## Power23      1.285e-01  4.330e-04 296.830 < 2e-16 ***
## Power24      1.279e-01  3.670e-04 348.341 < 2e-16 ***
## Power25      1.247e-01  4.654e-04 267.983 < 2e-16 ***
## Power26      1.290e-01  5.174e-04 249.344 < 2e-16 ***
## Power27      1.285e-01  5.085e-04 252.617 < 2e-16 ***
## Power28      1.295e-01  4.052e-04 319.668 < 2e-16 ***
## Power29      1.240e-01  4.533e-04 273.545 < 2e-16 ***
## Power30      1.293e-01  4.955e-04 260.886 < 2e-16 ***
## Power31      1.313e-01  5.202e-04 252.365 < 2e-16 ***
## Power32      1.348e-01  4.676e-04 288.257 < 2e-16 ***
## Power33      1.315e-01  4.222e-04 311.509 < 2e-16 ***
## Power34      1.300e-01  5.134e-04 253.211 < 2e-16 ***
## Power35      1.310e-01  4.840e-04 270.745 < 2e-16 ***
## Power36      1.356e-01  4.405e-04 307.893 < 2e-16 ***
## Power37      1.343e-01  4.286e-04 313.309 < 2e-16 ***
## Power38      1.300e-01  4.783e-04 271.764 < 2e-16 ***
## Power39      1.369e-01  5.329e-04 256.807 < 2e-16 ***
## Power40      1.373e-01  5.073e-04 270.683 < 2e-16 ***
## Power41      1.287e-01  4.652e-04 276.775 < 2e-16 ***
## Power42      1.394e-01  5.830e-04 239.160 < 2e-16 ***
## Power43      1.438e-01  6.136e-04 234.329 < 2e-16 ***
## Power44      1.372e-01  5.997e-04 228.840 < 2e-16 ***
## Power45      1.491e-01  7.518e-04 198.276 < 2e-16 ***
## Power46      1.560e-01  8.716e-04 179.000 < 2e-16 ***
## Power47      1.602e-01  1.044e-03 153.391 < 2e-16 ***
## Power48      1.516e-01  1.311e-03 115.672 < 2e-16 ***
## Power49      1.318e-01  1.108e-03 118.958 < 2e-16 ***
## qW           7.413e+01  2.651e+00  27.959 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6116 on 22218 degrees of freedom
## (1404 observations deleted due to missingness)
## Multiple R-squared:  0.9996, Adjusted R-squared:  0.9996
## F-statistic: 4.237e+05 on 134 and 22218 DF, p-value: < 2.2e-16
```

```
testing_energy.tx <- energy.tx.testing
# Make predictions on testing data
predictions_energy.tx.testing <- predict(result_energy.tx$model, newdata = testing_energy.tx)

# Calculate RMSE
rmse_energy.tx.training <- sqrt(mean((predictions_energy.tx.testing - testing_energy.tx$Total_Power)^2))
```

```
cat("RMSE for transformed energy dataset:", rmse_energy.tx.training, "\n")
```

```
## RMSE for transformed energy dataset: 0.6203251
```

Ques 2.8 Analysis of 3 models energy

Energy.training

Based on the first model. There seems an over fitting of data since the F1 score is quite high Indicating strong evidence against the null hypothesis (i.e., all coefficients are zero) and adjusted R square, R square are equal to 1. The range of residuals is quite large, from -2606.40 to 2931.24, indicating considerable variation in model performance for different observations. Since the RMSE (174203.5) is extremely high, indicating a large average difference between the predicted and observed values. Such a high RMSE value might suggest poor model performance or potential outliers affecting the model's accuracy. Given that the R-squared is 1 and the RMSE is extremely high, it's possible that the model is suffering from severe overfitting, which means it may not generalize well to new data.

Energy.no.training

Based on this model, it's better than energy.training model. But still it seems the case of overfitting. The model seems to fit the data very well, with an adjusted R-squared of 1. However, the residual standard error is 264.3 which represents the average difference between the observed and predicted values. Lower values indicate better fit. Since the scaling was done with z score, it has better RMSE than before. The RMSE for the no-energy training is 269.6416. This value represents the average prediction error of the model and is a measure of how well the model fits the data. Lower values of RMSE indicate better fit.

Energy.tx

The residual standard error (0.6111) gives an idea of the average deviation of the observed values from the predicted values by the model. Lower values of RMSE indicate a better fit of the model to the data. For every unit increase in X1, the Total_Power decreases by -8.524e-03 (assuming all other variables are constant). Similarly, the coefficients for other variables indicate the change in the Total_Power per unit increase in those variables. Even though the RMSE is small, the R square is 0.9996, Adjusted R-squared: 0.9996.

Question 2.9

For each of the predictive models, calculated the 95% prediction interval for the Total_Power for each data point in the validation data

```
# Function to calculate 95% prediction intervals
calculate_prediction_intervals <- function(model, validation_dataset) {
  predictions <- predict(model, newdata = validation_dataset, interval = "prediction", level = 0.95)
  prediction_intervals <- as.data.frame(predictions)
  colnames(prediction_intervals) <- c("Prediction", "LowerBound", "UpperBound")
  return(prediction_intervals)
}
```



```

# Call the backward_elimination function for energy.training dataset
result_energy_training <- backward_elimination(energy.training)

# Calculate 95% prediction intervals for energy.training dataset
prediction_intervals_energy_training <- calculate_prediction_intervals(result_energy_training$model, en

# Print the prediction intervals for energy training data
#print(prediction_intervals_energy_training)

# Call the backward_elimination function for no energy training dataset
result_energy_no_training <- backward_elimination(energy.no.training)

# Calculating 95% prediction intervals for no energy training dataset
prediction_intervals_energy_no_training <- calculate_prediction_intervals(result_energy_no_training$model, en

# printing the prediction intervals for energy no training data
#print(prediction_intervals_energy_no_training)

# Call the backward_elimination function for transformed energy training dataset
result_energy.tx <- backward_elimination(energy.tx.training)

prediction_intervals_energy.tx.training <- calculate_prediction_intervals(result_energy.tx$model, energ

# printing the prediction intervals for energy.tx transformed training data
#print(prediction_intervals_energy.tx.training)

```