STAT 46700/ CS 59000 Topics in Data Science **Spring 2025**
Midterm Test – Take home **Due: March 12, 2025**
Time: 11:59 PM(CST)

Please work ***individually*** and provide detail solution with R code embedded with your answers.

I affirm that I didn't give or receive any unauthorized help on this exam and that all work is my own [***Vaishak Balachandra***]

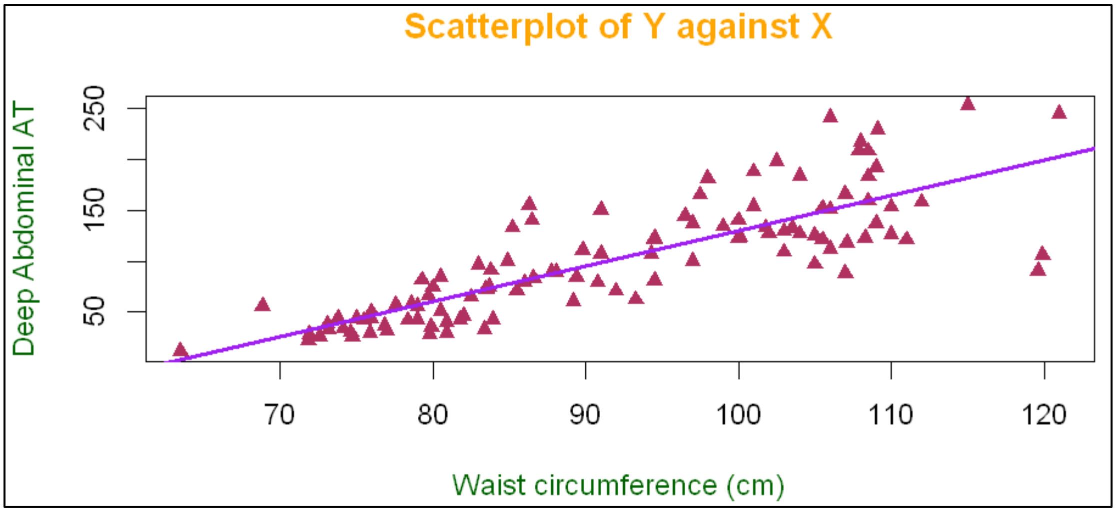
PUID: ***0037831852***

Q.N. 1) In order to investigate how well one can predict and estimate deep abdominal adipose tissue (AT) from the knowledge of the waist circumference Despres et al . (1991) collected a data from men between the ages of 18 and 42 years who were free from metabolic disease that would require treatment. The variable waist measurement will be used as a predictor variable. The dataset (**MIdtermQ1data)** is provided with this assignment in the Brightspace. Waist circumference (cm), X, and Deep Abdominal AT, Y, of a sample of men are analyzed.

- **a)** Import the data and determine how many men are included in this study.
- **b)** Fit a simple linear regression model. Please be sure to state the equation of the model and display the fitted line with the scattered plot.
- **c)** What is the value of the coefficient of determination? Please provide its interpretation.
- **d)** What is the predicted value of AT for a waist circumference of 105cm?
- **e)** Provide a 90% confidence interval and prediction interval of your estimated value in (d).

```
> # a
> Q1 <- read.table("C:/Users/PNW_checkout/Downloads/sem 2/0. Coursework/0. Coursework/Data science/
Vaishak_Balachandra_Midterm/MidterrmQ1.txt", header = T)
> head(Q1)
  ID      X      Y
1  1  74.75  25.72
2  2 103.00 129.00
3  3 108.00 217.00
4  4  72.60  25.89
5  5  80.00  74.02
6  6 100.00 140.00
> dim(Q1)
[1] 109   3
> names(Q1)
[1] "ID" "X"  "Y"
> attach(Q1)
> cat("109 mens are included in the given dataset")
109 mens are included in the given dataset
>
>
> # b
> plot(X,Y, main = "Scatterplot of Y against X", pch = 17, col = "maroon", col.main = "orange", col
.lab = "darkgreen", xlab = "Waist circumference (cm)", ylab = "Deep Abdominal AT")
> model1 <- lm(Y~X)
> model1
Call:
lm(formula = Y ~ X)

Coefficients:
(Intercept)            X
   -215.981        3.459
```

```
> cat("Linear Fitted Model Equation:
+ Y = -215.981 + 3.459*X
+ AT = -215.981 + 3.459*Waist")
Linear Fitted Model Equation:
Y = -215.981 + 3.459*X
AT = -215.981 + 3.459*Waist
> abline(model1, lwd = 2, col = "purple")
>
>
> # c
> summary(model1)

Call:
lm(formula = Y ~ X)

Residuals:
     Min       1Q   Median       3Q      Max
-107.288  -19.143   -2.939   16.376   90.342

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -215.9815    21.7963  -9.909   <2e-16 ***
X              3.4589     0.2347  14.740   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 33.06 on 107 degrees of freedom
Multiple R-squared:   0.67,  Adjusted R-squared:  0.667
F-statistic: 217.3 on 1 and 107 DF,  p-value: < 2.2e-16

> cat("Coefficient of Determination (R squared value) = 0.67 = 67%")
Coefficient of Determination (R squared value) = 0.67 = 67%
> cat("Inference: It means only 67% of the variability in Y(AT) is defined by X(Waist Circumference
)")
Inference: It means only 67% of the variability in Y(AT) is defined by X(Waist Circumference)
>
>
>
> # d
> predict(model1, data.frame(X = 105))
       1
147.1987
> cat("Here, For the waist circumference equals to 105cm, the AT is found to be 147.1987")
Here, For the waist circumference equals to 105cm, the AT is found to be 147.1987
> # e
> predict(model1, data.frame(X = 105), interval = "confidence", level = 0.9)
       fit      lwr      upr
1 147.1987 139.8762 154.5213
> cat("Confidence Interval: [139.8762, 154.5213]")
Confidence Interval: [139.8762, 154.5213]
> predict(model1, data.frame(X = 105), interval = "pred", level = 0.9)
       fit      lwr      upr
1 147.1987 91.85026 202.5472
> cat("Confidence Interval: [91.85026, 202.5472]")
Confidence Interval: [91.85026, 202.5472]
```



##

Q.N.2) The dataset (**Passenger**) provided with this assignment is sample data obtained from the accident data from data.gov which contains passenger's age and the speed of the vehicle(mph) at the time of impact and the fate of the passengers (1 -survived, 0- did not survive) after the crash.

a) Fit a logistic regression model. Please be sure to write the equation of the fitted model.
b) Find the probability that a 35-year-old passenger will survive if there was a crash of a car speeding at 80mph?

```
> # 2
> # a
> install.packages("readxl")
> library(readxl)
> Q2 <- read_excel("Passangers.xlsx")
> head(Q2)
# A tibble: 6 × 4
     ID   Age Speed Survived
  <dbl> <dbl> <dbl>    <dbl>
1     1    22    65        0
2     2    38    50        1
3     3    26    45        1
4     4    35    55        1
5     5    35    85        0
6     6    26   117        0
> dim(Q2)
[1] 20  4
> names(Q2)
[1] "ID"          "Age"        "Speed"     "Survived"
> attach(Q2)
> model2 <- glm(Survived~Age+Speed, family = "binomial")
> model2

Call:  glm(formula = Survived ~ Age + Speed, family = "binomial")

Coefficients:
(Intercept)          Age        Speed
    7.56052      0.05207     -0.14679

Degrees of Freedom: 19 Total (i.e. Null);  17 Residual
Null Deviance:          27.73
```

```
Residual Deviance: 13.32 	AIC: 19.32
> cat("Logistic Fitted Model Equation:
+ Survived = [1 + exp(-7.56052 - 0.05207*Age + 0.14679*Speed)]^(-1)")
Logistic Fitted Model Equation:
Survived = [1 + exp(-7.56052 - 0.05207*Age + 0.14679*Speed)]^(-1)
>
>
> # b
> predict(model2, data.frame(Age= 35, Speed = 80), type = "response")
         1
0.08625105
> cat("Probability that a 35-year-old passenger will survive if there was a crash of a car speeding
at 80mph is: 0.08625105 = 8.625105%")
Probability that a 35-year-old passenger will survive if there was a crash of a car speeding at 80m
ph is: 0.08625105 = 8.625105%

####################################################################################################
```

Q.N. 3) For risk management purposes, a credit card companies wants to predict the likelihood of their customers missing a payment in a given month. A publicly available data involving a cross-sectional sample of 30,000 customers from a major credit company in Taiwan are provided with this assignment (Credit_data). (If the last digit of your PUID is less than 5 please use the first 15000 data otherwise use the last 15000 data).

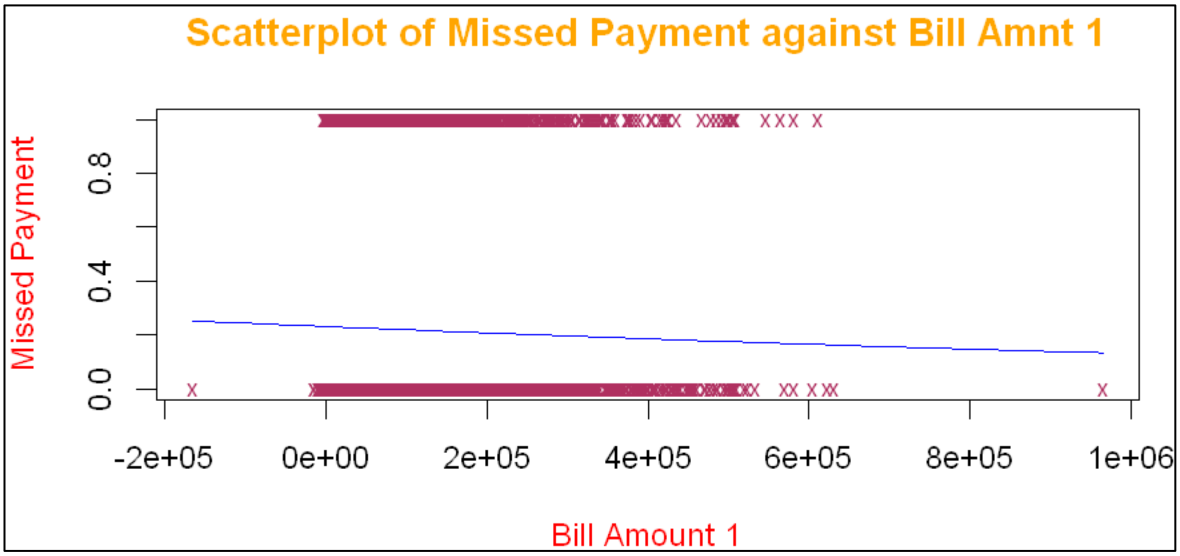
a) Import the data in R and print the variable names.
b) Fit a simple logistic regression model using MISSED_PAYMENT (1-Yes, 0-No) as the binary response and BILL_AMT1 as a predictor variable. Please write the model equation and display the fitted model on the scatterplot.
c) Create the confusion matrix to assess the classification accuracy (assume that probabilities exceeding 0.5 to a predicted missed payment in your model)
d) Fit a multiple logistic regression model using all possible predictors and assess the classification accuracy.

```
> # 3
>
> # a
> Q3_initial <- read.csv("Credit_data.csv")
> head(Q3_initial)
  ID LIMIT_BAL SEX EDUCATION MARRIAGE AGE PAY_0 PAY_2 PAY_3 PAY_4 PAY_5 PAY_6 BILL_AMT1
1  1     20000   2         2        1  24     2     2    -1    -1    -2    -2      3913
2  2    120000   2         2        2  26    -1     2     0     0     0     2      2682
3  3     90000   2         2        2  34     0     0     0     0     0     0     29239
4  4     50000   2         2        1  37     0     0     0     0     0     0     46990
5  5     50000   1         2        1  57    -1     0    -1     0     0     0      8617
6  6     50000   1         1        2  37     0     0     0     0     0     0     64400
  BILL_AMT2 BILL_AMT3 BILL_AMT4 BILL_AMT5 BILL_AMT6 PAY_AMT1 PAY_AMT2 PAY_AMT3 PAY_AMT4
1      3102       689         0         0         0        0      689        0        0
2      1725      2682      3272      3455      3261        0     1000     1000     1000
3     14027     13559     14331     14948     15549     1518     1500     1000     1000
4     48233     49291     28314     28959     29547     2000     2019     1200     1100
5      5670     35835     20940     19146     19131     2000    36681    10000     9000
6     57069     57608     19394     19619     20024     2500     1815      657     1000
  PAY_AMT5 PAY_AMT6 MISSED_PAYMENT
1        0        0              1
2        0     2000              1
3     1000     5000              0
4     1069     1000              0
```

```
5      689      679              0
6     1000      800              0
> dim(Q3_initial)
[1] 30000    25
> names(Q3_initial)
 [1] "ID"             "LIMIT_BAL"      "SEX"            "EDUCATION"      "MARRIAGE"
 [6] "AGE"            "PAY_0"          "PAY_2"          "PAY_3"          "PAY_4"
[11] "PAY_5"          "PAY_6"          "BILL_AMT1"      "BILL_AMT2"      "BILL_AMT3"
[16] "BILL_AMT4"      "BILL_AMT5"      "BILL_AMT6"      "PAY_AMT1"       "PAY_AMT2"
[21] "PAY_AMT3"       "PAY_AMT4"       "PAY_AMT5"       "PAY_AMT6"       "MISSED_PAYMENT"
> attach(Q3_initial)
>
> # Since, my PUID ends with 2 <5, I'm choosing the first 15000 rows
> Q3 <- Q3_initial[1:15000, ]
> dim(Q3)
[1] 15000    25
>
> # b
> plot(Q3$BILL_AMT1, Q3$MISSED_PAYMENT, pch = "x", col = "maroon",main = "Scatterplot of Missed Pay
ment against Bill Amnt 1", col.main = "orange", col.lab = "red", cex = 0.75, xlab = "Bill Amount 1"
, ylab = "Missed Payment")
> model3 <- glm(MISSED_PAYMENT ~ BILL_AMT1, data = Q3, family = "binomial")
> summary(model3)

Call:
glm(formula = MISSED_PAYMENT ~ BILL_AMT1, family = "binomial",
    data = Q3)

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept) -1.202e+00  2.372e-02 -50.671   <2e-16 ***
BILL_AMT1   -6.967e-07  2.824e-07  -2.468   0.0136 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 16000  on 14999  degrees of freedom
Residual deviance: 15994  on 14998  degrees of freedom
AIC: 15998

Number of Fisher Scoring iterations: 4

> cat("Logistic Fitted Model Equation: MISSED_PAYMENT = [1 + exp(-(1.202 + 0.0000006967*BILL_AMT1))
]^(-1)")
Logistic Fitted Model Equation: MISSED_PAYMENT = [1 + exp(-(1.202 + 0.0000006967*BILL_AMT1))]^(-1)
> curve(predict(model3, newdata = data.frame(BILL_AMT1 = x), type = "response"), col = "blue", add
= TRUE)
>
> # c
> # summary(model3)
> p = predict(model3, data = Q3, type = 'response')
> pp =ifelse(p > 0.5, 1, 0)
> # install.packages("caret")
> library(caret)
> confusionMatrix(data = factor(pp), reference = factor(Q3$MISSED_PAYMENT), positive = "1")
Confusion Matrix and Statistics

          Reference
Prediction     0     1
         0 11623  3377
         1     0     0

               Accuracy : 0.7749
                 95% CI : (0.7681, 0.7815)
    No Information Rate : 0.7749
    P-Value [Acc > NIR] : 0.5046
```

```
                  Kappa : 0

 Mcnemar's Test P-Value : <2e-16

            Sensitivity : 0.0000
            Specificity : 1.0000
         Pos Pred Value :    NaN
         Neg Pred Value : 0.7749
             Prevalence : 0.2251
         Detection Rate : 0.0000
   Detection Prevalence : 0.0000
      Balanced Accuracy : 0.5000

       'Positive' Class : 1
> cat("Accuracy = 0.7749 = 77.49%")
Accuracy = 0.7749 = 77.49%
>
> # d
> names(Q3)
 [1] "ID"               "LIMIT_BAL"        "SEX"              "EDUCATION"        "MARRIAGE"
 [6] "AGE"              "PAY_0"            "PAY_2"            "PAY_3"            "PAY_4"
[11] "PAY_5"            "PAY_6"            "BILL_AMT1"        "BILL_AMT2"        "BILL_AMT3"
[16] "BILL_AMT4"        "BILL_AMT5"        "BILL_AMT6"        "PAY_AMT1"         "PAY_AMT2"
[21] "PAY_AMT3"         "PAY_AMT4"         "PAY_AMT5"         "PAY_AMT6"         "MISSED_PAYMENT"
> model3a <- glm(MISSED_PAYMENT~., family = "binomial", data = Q3)
> model3a

Call:  glm(formula = MISSED_PAYMENT ~ ., family = "binomial", data = Q3)

Coefficients:
(Intercept)           ID    LIMIT_BAL          SEX    EDUCATION     MARRIAGE          AGE
 -5.317e-01    1.814e-06   -2.799e-07   -8.916e-02   -1.207e-01   -1.895e-01    3.475e-03
      PAY_0        PAY_2        PAY_3        PAY_4        PAY_5        PAY_6    BILL_AMT1
  5.461e-01    4.594e-02    8.254e-02    4.619e-03    8.237e-02   -2.019e-02   -7.360e-06
  BILL_AMT2    BILL_AMT3    BILL_AMT4    BILL_AMT5    BILL_AMT6     PAY_AMT1     PAY_AMT2
  4.647e-06   -5.036e-07    3.016e-07    1.488e-06    5.894e-07   -1.873e-05   -6.773e-06
   PAY_AMT3     PAY_AMT4     PAY_AMT5     PAY_AMT6
 -6.278e-06   -2.961e-06   -1.959e-06   -1.471e-06

Degrees of Freedom: 14999 Total (i.e. Null);  14975 Residual
Null Deviance:         16000
Residual Deviance: 14330     AIC: 14380
> p1 = predict(model3a, data = Q3, type = 'response')
> pp1 =ifelse(p1 > 0.5, 1, 0)
> library(caret)
> confusionMatrix(data = factor(pp1), reference = factor(Q3$MISSED_PAYMENT), positive = "1")
Confusion Matrix and Statistics

          Reference
Prediction     0     1
         0 11339  2694
         1   284   683

               Accuracy : 0.8015
                 95% CI : (0.795, 0.8078)
    No Information Rate : 0.7749
    P-Value [Acc > NIR] : 1.352e-15

                  Kappa : 0.2381

 Mcnemar's Test P-Value : < 2.2e-16

            Sensitivity : 0.20225
            Specificity : 0.97557
         Pos Pred Value : 0.70631
         Neg Pred Value : 0.80802
```

```
            Prevalence : 0.22513
        Detection Rate : 0.04553
  Detection Prevalence : 0.06447
     Balanced Accuracy : 0.58891

      'Positive' Class : 1

> cat("Accuracy = 0.8015 = 80.15%")
Accuracy = 0.8015 = 80.15%
> cat("The curve in the plot appears like a stright line, as the effect size of BILL_AMT1 on the proba
bility of missed payment is very small (i.e., coefficient is 0.0000006967), meaning the relationship i
s weak.")
The curve in the plot appears like a stright line, as the effect size of BILL_AMT1 on the probability
of missed payment is very small (i.e., coefficient is 0.0000006967), meaning the relationship is weak.
```




```
####################################################################################################
```

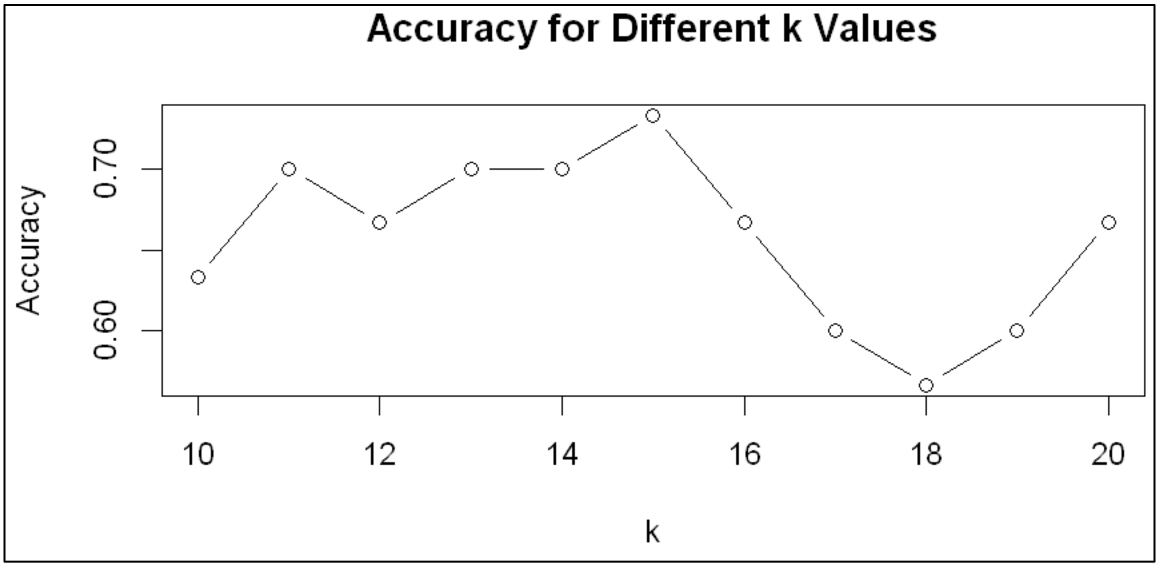
Q.N. 4) Consider the data related to the entering high-school students who make program choices among general programs, vocational programs and academic programs. Their choices might be modeled using their reading, writing, math, science scores and social economic status. The data sets are available with this assignment (**program_data**).

a) Create a KNN-based classifier for program choice using the variables `ses`,`prog`,`read`, `write`, `math`, `science`, `socst` of students. (Make sure that you have normalize the data and use 80% data for training and 20% for testing. Please be sure to use set.seed() function for reproducibility of your results.

b) Evaluate the classifier's accuracy in predicting which academic program the student will be joining.

```
> # 4
> # a
> library(readxl)
> Q4 <- read_excel("program_data.xlsx")
> head(Q4)
# A tibble: 6 × 13
     id female ses     schtyp prog      read write  math science socst honors       awards    cid
```

```
  <dbl> <chr>  <chr>  <chr>  <chr>     <dbl> <dbl> <dbl>   <dbl> <dbl> <chr>         <dbl> <dbl>
1    45 female low    public vocation    34    35    41      29    26 not enrolled      0     1
2   108 male   middle public general     34    33    41      36    36 not enrolled      0     1
3    15 male   high   public vocation    39    39    44      26    42 not enrolled      0     1
4    67 male   low    public vocation    37    37    42      33    32 not enrolled      0     1
5   153 male   middle public vocation    39    31    40      39    51 not enrolled      0     1
6    51 female high   public general     42    36    42      31    39 not enrolled      0     1
> names(Q4)
 [1] "id"      "female"  "ses"     "schtyp"  "prog"     "read"     "write"    "math"     "science"
[10] "socst"   "honors"  "awards"  "cid"
> dim(Q4)
[1] 150  13
> set.seed(2467)
> rnum <- sample(1:nrow(Q4))
> Q4 <- Q4[rnum,]
> Q4$ses <- as.numeric(as.factor(Q4$ses))
> prog_factor <- as.factor(Q4$prog)
> # min-max normalization
> normalize <- function(x){
+   return ((x-min(x))/(max(x)-min(x)))
+ }
> Q4_norm <- as.data.frame(lapply(Q4[,c("ses", "read", "write", "math", "science", "socst")], norma
lize))
> head(Q4_norm)
  ses      read     write      math   science     socst
1 0.0 0.5945946 0.3235294 0.5151515 0.2173913 0.7777778
2 1.0 0.7297297 0.2352941 0.7272727 0.5869565 0.4444444
3 1.0 0.7837838 0.7647059 0.8181818 0.6956522 0.6666667
4 1.0 0.2972973 0.6764706 0.6363636 0.5869565 0.3333333
5 0.5 0.2972973 0.6764706 0.1818182 0.4565217 0.2222222
6 0.0 0.5135135 0.6176471 0.3030303 0.4782609 0.7777778
> # Splitting the dataset
> set.seed(2467)
> train_index <- sample(1:nrow(Q4_norm), 0.8 * nrow(Q4_norm))
> train_data <- Q4_norm[train_index,]
> test_data <- Q4_norm[-train_index,]
> train_labels <- prog_factor[train_index]
> test_labels <- prog_factor[-train_index]
> # To find optimum k value
> set.seed(2467)
> k_values <- 10:20
> accuracies <- numeric(length(k_values))
> for(i in 1:length(k_values)) {
+   knn_pred <- knn(train = train_data, test = test_data, cl = train_labels, k = k_values[i])
+   accuracies[i] <- sum(knn_pred == test_labels) / length(test_labels)
+ }
> plot(k_values, accuracies, type="b", xlab="k", ylab="Accuracy", main="Accuracy for Different k Va
lues")
> cat("Best k:", 15)
Best k: 15
>
>
> # b
> library(class)
> knn_pred <- knn(train = train_data, test = test_data, cl = train_labels, k = 15)
> confusion_matrix <- table(Predicted = knn_pred, Actual = test_labels)
> print(confusion_matrix)
          Actual
Predicted  academic general vocation
  academic       13       2        1
  general         0       2        1
  vocation        3       3        5
> accuracy <- sum(knn_pred == test_labels) / length(test_labels)
> cat("Accuracy: 66.67%")
Accuracy: 66.67%
```


Accuracy for Different k Values
Accuracy
0.60
0.70
10
12
14
16
18
20
k