Homework 4

# 1)

library(ISLR)  
summary(College)

## Private Apps Accept Enroll Top10perc   
## No :212 Min. : 81 Min. : 72 Min. : 35 Min. : 1.00   
## Yes:565 1st Qu.: 776 1st Qu.: 604 1st Qu.: 242 1st Qu.:15.00   
## Median : 1558 Median : 1110 Median : 434 Median :23.00   
## Mean : 3002 Mean : 2019 Mean : 780 Mean :27.56   
## 3rd Qu.: 3624 3rd Qu.: 2424 3rd Qu.: 902 3rd Qu.:35.00   
## Max. :48094 Max. :26330 Max. :6392 Max. :96.00   
## Top25perc F.Undergrad P.Undergrad Outstate   
## Min. : 9.0 Min. : 139 Min. : 1.0 Min. : 2340   
## 1st Qu.: 41.0 1st Qu.: 992 1st Qu.: 95.0 1st Qu.: 7320   
## Median : 54.0 Median : 1707 Median : 353.0 Median : 9990   
## Mean : 55.8 Mean : 3700 Mean : 855.3 Mean :10441   
## 3rd Qu.: 69.0 3rd Qu.: 4005 3rd Qu.: 967.0 3rd Qu.:12925   
## Max. :100.0 Max. :31643 Max. :21836.0 Max. :21700   
## Room.Board Books Personal PhD   
## Min. :1780 Min. : 96.0 Min. : 250 Min. : 8.00   
## 1st Qu.:3597 1st Qu.: 470.0 1st Qu.: 850 1st Qu.: 62.00   
## Median :4200 Median : 500.0 Median :1200 Median : 75.00   
## Mean :4358 Mean : 549.4 Mean :1341 Mean : 72.66   
## 3rd Qu.:5050 3rd Qu.: 600.0 3rd Qu.:1700 3rd Qu.: 85.00   
## Max. :8124 Max. :2340.0 Max. :6800 Max. :103.00   
## Terminal S.F.Ratio perc.alumni Expend   
## Min. : 24.0 Min. : 2.50 Min. : 0.00 Min. : 3186   
## 1st Qu.: 71.0 1st Qu.:11.50 1st Qu.:13.00 1st Qu.: 6751   
## Median : 82.0 Median :13.60 Median :21.00 Median : 8377   
## Mean : 79.7 Mean :14.09 Mean :22.74 Mean : 9660   
## 3rd Qu.: 92.0 3rd Qu.:16.50 3rd Qu.:31.00 3rd Qu.:10830   
## Max. :100.0 Max. :39.80 Max. :64.00 Max. :56233   
## Grad.Rate   
## Min. : 10.00   
## 1st Qu.: 53.00   
## Median : 65.00   
## Mean : 65.46   
## 3rd Qu.: 78.00   
## Max. :118.00

library(ggplot2)  
library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ tibble 3.0.5 ✓ dplyr 1.0.3  
## ✓ tidyr 1.1.2 ✓ stringr 1.4.0  
## ✓ readr 1.4.0 ✓ forcats 0.5.0  
## ✓ purrr 0.3.4

## ── Conflicts ────────────────────────────────────────── tidyverse\_conflicts() ──  
## x dplyr::filter() masks stats::filter()  
## x dplyr::lag() masks stats::lag()

attach(College)  
#install.packages("leaps")  
library(leaps)  
#attach(Advertising)

### 1.b - 1.c

bestsub = regsubsets(x = Outstate ~ Private + Apps + Accept + Enroll + Top10perc + Top25perc + F.Undergrad + P.Undergrad + Room.Board + Books + Personal + PhD + Terminal + S.F.Ratio + perc.alumni + Expend + Grad.Rate, data = College)  
  
forward = regsubsets(x = Outstate ~ Private + Apps + Accept + Enroll + Top10perc + Top25perc + F.Undergrad + P.Undergrad + Room.Board + Books + Personal + PhD + Terminal + S.F.Ratio + perc.alumni + Expend + Grad.Rate, data = College, method = "forward")  
  
backward = regsubsets(x = Outstate ~ Private + Apps + Accept + Enroll + Top10perc + Top25perc + F.Undergrad + P.Undergrad + Room.Board + Books + Personal + PhD + Terminal + S.F.Ratio + perc.alumni + Expend + Grad.Rate, data = College, method = "backward")

#summary(bestsub)  
bestsub.sum = summary(bestsub)  
# names(bestsub.sum)  
  
bestsub.sum$adjr2

## [1] 0.4519248 0.6053449 0.6813703 0.7177545 0.7353207 0.7461196 0.7482083  
## [8] 0.7534107

bestsub.sum$cp

## [1] 1020.96124 519.11926 271.24809 153.27067 96.87747 62.64080 56.78449  
## [8] 40.84661

bestsub.sum$bic

## [1] -454.9344 -704.4492 -865.0628 -953.6261 -997.9067 -1024.6260 -1025.3994  
## [8] -1035.9770

forward.sum = summary(forward)  
# names(forward.sum)  
forward.sum$adjr2

## [1] 0.4519248 0.6053449 0.6813703 0.7177545 0.7353207 0.7453502 0.7475908  
## [8] 0.7494312

forward.sum$cp

## [1] 1020.96124 519.11926 271.24809 153.27067 96.87747 65.14282 58.79017  
## [8] 53.75465

forward.sum$bic

## [1] -454.9344 -704.4492 -865.0628 -953.6261 -997.9067 -1022.2749 -1023.4961  
## [8] -1023.5377

backward.sum = summary(backward)  
backward.sum$adjr2

## [1] 0.4519248 0.6053449 0.6813703 0.7177545 0.7346671 0.7461196 0.7467455  
## [8] 0.7534107

backward.sum$cp

## [1] 1020.96124 519.11926 271.24809 153.27067 99.00568 62.64080 61.53553  
## [8] 40.84661

backward.sum$bic

## [1] -454.9344 -704.4492 -865.0628 -953.6261 -995.9904 -1024.6260 -1020.8984  
## [8] -1035.9770

summary(bestsub)

## Subset selection object  
## Call: regsubsets.formula(x = Outstate ~ Private + Apps + Accept + Enroll +   
## Top10perc + Top25perc + F.Undergrad + P.Undergrad + Room.Board +   
## Books + Personal + PhD + Terminal + S.F.Ratio + perc.alumni +   
## Expend + Grad.Rate, data = College)  
## 17 Variables (and intercept)  
## Forced in Forced out  
## PrivateYes FALSE FALSE  
## Apps FALSE FALSE  
## Accept FALSE FALSE  
## Enroll FALSE FALSE  
## Top10perc FALSE FALSE  
## Top25perc FALSE FALSE  
## F.Undergrad FALSE FALSE  
## P.Undergrad FALSE FALSE  
## Room.Board FALSE FALSE  
## Books FALSE FALSE  
## Personal FALSE FALSE  
## PhD FALSE FALSE  
## Terminal FALSE FALSE  
## S.F.Ratio FALSE FALSE  
## perc.alumni FALSE FALSE  
## Expend FALSE FALSE  
## Grad.Rate FALSE FALSE  
## 1 subsets of each size up to 8  
## Selection Algorithm: exhaustive  
## PrivateYes Apps Accept Enroll Top10perc Top25perc F.Undergrad  
## 1 ( 1 ) " " " " " " " " " " " " " "   
## 2 ( 1 ) "\*" " " " " " " " " " " " "   
## 3 ( 1 ) "\*" " " " " " " " " " " " "   
## 4 ( 1 ) "\*" " " " " " " " " " " " "   
## 5 ( 1 ) "\*" " " " " " " " " " " " "   
## 6 ( 1 ) "\*" " " " " " " " " " " " "   
## 7 ( 1 ) "\*" " " " " " " " " " " " "   
## 8 ( 1 ) "\*" " " "\*" " " " " " " "\*"   
## P.Undergrad Room.Board Books Personal PhD Terminal S.F.Ratio  
## 1 ( 1 ) " " " " " " " " " " " " " "   
## 2 ( 1 ) " " " " " " " " " " " " " "   
## 3 ( 1 ) " " "\*" " " " " " " " " " "   
## 4 ( 1 ) " " "\*" " " " " " " " " " "   
## 5 ( 1 ) " " "\*" " " " " "\*" " " " "   
## 6 ( 1 ) " " "\*" " " " " " " "\*" " "   
## 7 ( 1 ) " " "\*" " " "\*" " " "\*" " "   
## 8 ( 1 ) " " "\*" " " " " " " "\*" " "   
## perc.alumni Expend Grad.Rate  
## 1 ( 1 ) " " "\*" " "   
## 2 ( 1 ) " " "\*" " "   
## 3 ( 1 ) " " "\*" " "   
## 4 ( 1 ) "\*" "\*" " "   
## 5 ( 1 ) "\*" "\*" " "   
## 6 ( 1 ) "\*" "\*" "\*"   
## 7 ( 1 ) "\*" "\*" "\*"   
## 8 ( 1 ) "\*" "\*" "\*"

summary(forward)

## Subset selection object  
## Call: regsubsets.formula(x = Outstate ~ Private + Apps + Accept + Enroll +   
## Top10perc + Top25perc + F.Undergrad + P.Undergrad + Room.Board +   
## Books + Personal + PhD + Terminal + S.F.Ratio + perc.alumni +   
## Expend + Grad.Rate, data = College, method = "forward")  
## 17 Variables (and intercept)  
## Forced in Forced out  
## PrivateYes FALSE FALSE  
## Apps FALSE FALSE  
## Accept FALSE FALSE  
## Enroll FALSE FALSE  
## Top10perc FALSE FALSE  
## Top25perc FALSE FALSE  
## F.Undergrad FALSE FALSE  
## P.Undergrad FALSE FALSE  
## Room.Board FALSE FALSE  
## Books FALSE FALSE  
## Personal FALSE FALSE  
## PhD FALSE FALSE  
## Terminal FALSE FALSE  
## S.F.Ratio FALSE FALSE  
## perc.alumni FALSE FALSE  
## Expend FALSE FALSE  
## Grad.Rate FALSE FALSE  
## 1 subsets of each size up to 8  
## Selection Algorithm: forward  
## PrivateYes Apps Accept Enroll Top10perc Top25perc F.Undergrad  
## 1 ( 1 ) " " " " " " " " " " " " " "   
## 2 ( 1 ) "\*" " " " " " " " " " " " "   
## 3 ( 1 ) "\*" " " " " " " " " " " " "   
## 4 ( 1 ) "\*" " " " " " " " " " " " "   
## 5 ( 1 ) "\*" " " " " " " " " " " " "   
## 6 ( 1 ) "\*" " " " " " " " " " " " "   
## 7 ( 1 ) "\*" " " " " " " " " " " " "   
## 8 ( 1 ) "\*" " " " " " " " " " " " "   
## P.Undergrad Room.Board Books Personal PhD Terminal S.F.Ratio  
## 1 ( 1 ) " " " " " " " " " " " " " "   
## 2 ( 1 ) " " " " " " " " " " " " " "   
## 3 ( 1 ) " " "\*" " " " " " " " " " "   
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## 5 ( 1 ) " " "\*" " " " " "\*" " " " "   
## 6 ( 1 ) " " "\*" " " " " "\*" " " " "   
## 7 ( 1 ) " " "\*" " " "\*" "\*" " " " "   
## 8 ( 1 ) " " "\*" " " "\*" "\*" "\*" " "   
## perc.alumni Expend Grad.Rate  
## 1 ( 1 ) " " "\*" " "   
## 2 ( 1 ) " " "\*" " "   
## 3 ( 1 ) " " "\*" " "   
## 4 ( 1 ) "\*" "\*" " "   
## 5 ( 1 ) "\*" "\*" " "   
## 6 ( 1 ) "\*" "\*" "\*"   
## 7 ( 1 ) "\*" "\*" "\*"   
## 8 ( 1 ) "\*" "\*" "\*"

summary(backward)

## Subset selection object  
## Call: regsubsets.formula(x = Outstate ~ Private + Apps + Accept + Enroll +   
## Top10perc + Top25perc + F.Undergrad + P.Undergrad + Room.Board +   
## Books + Personal + PhD + Terminal + S.F.Ratio + perc.alumni +   
## Expend + Grad.Rate, data = College, method = "backward")  
## 17 Variables (and intercept)  
## Forced in Forced out  
## PrivateYes FALSE FALSE  
## Apps FALSE FALSE  
## Accept FALSE FALSE  
## Enroll FALSE FALSE  
## Top10perc FALSE FALSE  
## Top25perc FALSE FALSE  
## F.Undergrad FALSE FALSE  
## P.Undergrad FALSE FALSE  
## Room.Board FALSE FALSE  
## Books FALSE FALSE  
## Personal FALSE FALSE  
## PhD FALSE FALSE  
## Terminal FALSE FALSE  
## S.F.Ratio FALSE FALSE  
## perc.alumni FALSE FALSE  
## Expend FALSE FALSE  
## Grad.Rate FALSE FALSE  
## 1 subsets of each size up to 8  
## Selection Algorithm: backward  
## PrivateYes Apps Accept Enroll Top10perc Top25perc F.Undergrad  
## 1 ( 1 ) " " " " " " " " " " " " " "   
## 2 ( 1 ) "\*" " " " " " " " " " " " "   
## 3 ( 1 ) "\*" " " " " " " " " " " " "   
## 4 ( 1 ) "\*" " " " " " " " " " " " "   
## 5 ( 1 ) "\*" " " " " " " " " " " " "   
## 6 ( 1 ) "\*" " " " " " " " " " " " "   
## 7 ( 1 ) "\*" " " "\*" " " " " " " " "   
## 8 ( 1 ) "\*" " " "\*" " " " " " " "\*"   
## P.Undergrad Room.Board Books Personal PhD Terminal S.F.Ratio  
## 1 ( 1 ) " " " " " " " " " " " " " "   
## 2 ( 1 ) " " " " " " " " " " " " " "   
## 3 ( 1 ) " " "\*" " " " " " " " " " "   
## 4 ( 1 ) " " "\*" " " " " " " " " " "   
## 5 ( 1 ) " " "\*" " " " " " " "\*" " "   
## 6 ( 1 ) " " "\*" " " " " " " "\*" " "   
## 7 ( 1 ) " " "\*" " " " " " " "\*" " "   
## 8 ( 1 ) " " "\*" " " " " " " "\*" " "   
## perc.alumni Expend Grad.Rate  
## 1 ( 1 ) " " "\*" " "   
## 2 ( 1 ) " " "\*" " "   
## 3 ( 1 ) " " "\*" " "   
## 4 ( 1 ) "\*" "\*" " "   
## 5 ( 1 ) "\*" "\*" " "   
## 6 ( 1 ) "\*" "\*" "\*"   
## 7 ( 1 ) "\*" "\*" "\*"   
## 8 ( 1 ) "\*" "\*" "\*"

summary(Expend)

## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## 3186 6751 8377 9660 10830 56233

### 2f

* three estimates for the number of features in the overal ‘best’ model

coef(backward, 3)

## (Intercept) PrivateYes Room.Board Expend   
## -145.0140299 2990.7338536 1.2100877 0.3248353

coef(bestsub, 3)

## (Intercept) PrivateYes Room.Board Expend   
## -145.0140299 2990.7338536 1.2100877 0.3248353

# 2

# create the training set  
set.seed(1)  
train = sample(c(TRUE, FALSE), nrow(College), rep = TRUE)  
  
# us remaining data at test set  
test = (!train)

* performing regularization in R

# install.packages("glmnet")  
library(glmnet)

## Loading required package: Matrix

##   
## Attaching package: 'Matrix'

## The following objects are masked from 'package:tidyr':  
##   
## expand, pack, unpack

## Loaded glmnet 4.1-1

* us glmnet() to create a matrix of features of College

features = model.matrix(Outstate ~ ., data = College)[,-1]

* tuning lambda

set.seed(1)  
cv.out = cv.glmnet(features[train,], College$Outstate[train], alpha = 0)  
  
# get the lambda by taking the min of CV error  
bestlam = cv.out$lambda.min  
bestlam

## [1] 665.1587

* preforming ridge regression on College

ridge = glmnet(x = features[train,], y = College$Outstate[train], alpha = 0, lambda = bestlam)

* calculate the test MSE for the value of lambda yielding the smallest CV error

ridge.pred = predict(ridge, s = bestlam, newx = features[test, ])  
ridge.pred

## 1  
## Adelphi University 10568.630  
## Alaska Pacific University 8702.492  
## Albright College 12299.602  
## Alderson-Broaddus College 7982.261  
## American International College 10447.978  
## Amherst College 18052.363  
## Anderson University 8642.098  
## Andrews University 8713.060  
## Assumption College 13641.209  
## Augustana College IL 12342.979  
## Augustana College 9921.579  
## Austin College 12660.198  
## Baker University 9260.483  
## Bard College 15638.145  
## Barry University 10895.166  
## Baylor University 11006.710  
## Beaver College 12698.747  
## Bellarmine College 10422.698  
## Belmont University 9454.490  
## Beloit College 11839.562  
## Bemidji State University 4294.181  
## Benedictine College 9387.232  
## Bennington College 11468.892  
## Bethany College 9071.772  
## Bethel College 7726.747  
## Bethune Cookman College 7137.326  
## Bloomsburg Univ. of Pennsylvania 6371.929  
## Bluefield College 8217.848  
## Bluffton College 10146.868  
## Bowling Green State University 6778.382  
## Bradford College 12607.612  
## Bradley University 11622.406  
## Brandeis University 16155.970  
## Brenau University 10751.655  
## Brewton-Parker College 5741.133  
## Bridgewater College 11479.502  
## Brigham Young University at Provo 9569.953  
## Brown University 17697.980  
## Bryn Mawr College 17818.740  
## Cabrini College 12285.887  
## Caldwell College 11104.562  
## California State University at Fresno 7028.804  
## Calvin College 11264.287  
## Campbell University 8880.528  
## Capitol College 7011.033  
## Carnegie Mellon University 16664.504  
## Carson-Newman College 9048.788  
## Castleton State College 8341.505  
## Catawba College 10074.457  
## Cedarville College 10239.728  
## Centenary College 10564.233  
## Center for Creative Studies 11245.825  
## Central College 11223.940  
## Central Connecticut State University 5998.920  
## Chapman University 11665.858  
## Claflin College 7903.811  
## Claremont McKenna College 17620.376  
## Clark University 13101.434  
## Clarke College 10178.861  
## Clemson University 8013.597  
## Clinch Valley Coll. of the Univ. of Virginia 5338.811  
## Coe College 11419.207  
## Coker College 11586.413  
## College Misericordia 12382.448  
## College of Mount St. Vincent 13225.844  
## College of Notre Dame 10408.230  
## College of Saint Elizabeth 11988.981  
## College of Santa Fe 9359.983  
## College of St. Scholastica 10709.262  
## College of the Holy Cross 16951.721  
## College of William and Mary 11435.440  
## Colorado College 14609.408  
## Columbia College 10861.934  
## Concordia College at St. Paul 8940.645  
## Concordia Lutheran College 8320.195  
## Concordia University CA 9804.583  
## Converse College 11511.948  
## D'Youville College 10464.452  
## Dana College 8421.805  
## Daniel Webster College 9805.302  
## Dartmouth College 19744.670  
## Davidson College 16382.909  
## DePauw University 13796.463  
## Dillard University 8832.904  
## Dordt College 8194.408  
## Drew University 15308.943  
## Earlham College 13939.990  
## East Carolina University 6932.542  
## East Tennessee State University 5665.762  
## East Texas Baptist University 6618.584  
## Eastern Connecticut State University 7326.190  
## Elmira College 11321.840  
## Elon College 9659.593  
## Emory University 18646.844  
## Erskine College 11875.379  
## Eureka College 10718.331  
## Evergreen State College 8073.181  
## Fayetteville State University 4707.907  
## Florida Institute of Technology 10833.951  
## Florida International University 6242.197  
## Florida State University 8202.921  
## Fontbonne College 8328.705  
## Fordham University 13729.964  
## Franciscan University of Steubenville 9710.289  
## Furman University 13153.766  
## George Fox College 9365.855  
## George Mason University 7601.664  
## Georgetown College 10622.831  
## Georgetown University 17300.237  
## Georgia Institute of Technology 11396.612  
## Georgia State University 4026.389  
## Georgian Court College 9987.840  
## Goldey Beacom College 4620.638  
## Goshen College 11078.271  
## Greensboro College 9448.601  
## Greenville College 9862.347  
## Grinnell College 16133.660  
## Grove City College 10104.075  
## Guilford College 11874.896  
## Gustavus Adolphus College 13018.619  
## Gwynedd Mercy College 11610.634  
## Hamline University 12439.561  
## Hampton University 8698.961  
## Hardin-Simmons University 7658.710  
## Hartwick College 12635.799  
## Harvey Mudd College 19244.913  
## Hobart and William Smith Colleges 14904.127  
## Hood College 14183.728  
## Hope College 12226.779  
## Husson College 7257.405  
## Illinois Institute of Technology 12617.682  
## Illinois State University 5621.646  
## Illinois Wesleyan University 12849.714  
## Immaculata College 11386.243  
## Indiana State University 5525.994  
## Iona College 12112.394  
## Iowa State University 7224.354  
## Ithaca College 13150.760  
## James Madison University 9625.298  
## Jamestown College 7148.409  
## Jersey City State College 6537.360  
## John Carroll University 13266.431  
## Johns Hopkins University 23572.801  
## Johnson State College 7530.659  
## Judson College 9452.936  
## Juniata College 13568.707  
## Kansas State University 6180.102  
## Kansas Wesleyan University 8368.966  
## Kenyon College 14179.912  
## Keuka College 11303.492  
## King College 9483.393  
## Knox College 13243.487  
## La Salle University 11311.745  
## Lafayette College 15469.919  
## Lawrence University 14092.709  
## Le Moyne College 12718.954  
## Lebanon Valley College 12249.805  
## Lehigh University 15811.884  
## Livingstone College 10486.868  
## Longwood College 7067.145  
## Loras College 9799.003  
## Louisiana Tech University 4504.843  
## Loyola College 13772.728  
## Loyola Marymount University 13165.848  
## Loyola University 12370.658  
## Lycoming College 11113.492  
## Lynchburg College 11122.815  
## Lyndon State College 7128.859  
## MacMurray College 9934.974  
## Malone College 7696.945  
## Manhattan College 13920.932  
## Mankato State University 4656.878  
## Marian College of Fond du Lac 7968.847  
## Marietta College 12305.056  
## Marist College 12307.421  
## Marquette University 12361.780  
## Mary Washington College 9446.238  
## Marymount College Tarrytown 13487.285  
## Maryville College 11535.737  
## Marywood College 11240.933  
## Mayville State University 4721.902  
## McMurry University 7872.673  
## Meredith College 10341.564  
## Mesa State College 4125.837  
## Messiah College 12139.845  
## Michigan State University 8838.384  
## Michigan Technological University 8856.377  
## Millsaps College 12264.788  
## Milwaukee School of Engineering 8407.193  
## Mississippi State University 6352.944  
## Mississippi University for Women 4412.609  
## Monmouth College 10726.161  
## Montana College of Mineral Sci. & Tech. 8086.151  
## Moorhead State University 5855.703  
## Moravian College 12055.481  
## Morris College 7513.211  
## Mount Mary College 8784.594  
## Mount Mercy College 8687.269  
## Mount Vernon Nazarene College 7829.893  
## National-Louis University 9482.623  
## New Jersey Institute of Technology 10591.632  
## New Mexico Institute of Mining and Tech. 7864.908  
## North Carolina State University at Raleigh 11103.307  
## North Central College 14106.208  
## North Dakota State University 5795.908  
## North Park College 11256.836  
## Northern Illinois University 5864.291  
## Northwest Missouri State University 5376.246  
## Northwest Nazarene College 8354.276  
## Oakland University 7362.997  
## Ohio Wesleyan University 14315.877  
## Oklahoma Christian University 7341.139  
## Oklahoma State University 6227.961  
## Otterbein College 11437.546  
## Ouachita Baptist University 8350.714  
## Our Lady of the Lake University 8663.172  
## Pace University 11838.221  
## Pacific Lutheran University 11756.005  
## Pacific Union College 9444.000  
## Pembroke State University 5300.305  
## Pepperdine University 15951.950  
## Philadelphia Coll. of Textiles and Sci. 10345.953  
## Phillips University 9342.167  
## Pitzer College 14245.774  
## Point Loma Nazarene College 9896.182  
## Point Park College 9722.212  
## Providence College 13134.047  
## Purdue University at West Lafayette 8926.470  
## Quincy University 10839.986  
## Radford University 6900.534  
## Randolph-Macon College 11740.681  
## Randolph-Macon Woman's College 14750.218  
## Regis College 13857.750  
## Rhodes College 14674.901  
## Rider University 11758.482  
## Rollins College 13141.213  
## Rutgers State University at Newark 9257.123  
## Sacred Heart University 11785.133  
## Saint Cloud State University 4453.218  
## Saint Francis College 10485.539  
## Saint Joseph's College IN 9729.928  
## Saint Joseph's College 9478.835  
## Saint Mary's College 12789.851  
## Saint Mary's College of Minnesota 9071.093  
## Salisbury State University 7603.307  
## Scripps College 17850.524  
## Seattle University 11721.431  
## Seton Hall University 12611.027  
## Seton Hill College 11261.644  
## Shorter College 9004.297  
## Simmons College 14904.794  
## Simpson College 11525.730  
## Skidmore College 14669.573  
## South Dakota State University 5323.036  
## Southeast Missouri State University 5473.425  
## Southeastern Oklahoma State Univ. 4595.075  
## Southern California College 8451.156  
## Southwest State University 5988.265  
## Southwestern University 13371.425  
## Spalding University 9609.858  
## Spelman College 12122.675  
## St. John's College 13124.440  
## St. John Fisher College 12284.619  
## St. Mary's College of California 13343.186  
## St. Mary's College of Maryland 10160.852  
## St. Mary's University of San Antonio 9766.532  
## St. Norbert College 11996.935  
## St. Thomas Aquinas College 10278.867  
## Stephens College 10110.439  
## Stetson University 12206.944  
## Stockton College of New Jersey 7585.982  
## SUNY at Binghamton 10241.282  
## SUNY at Stony Brook 9999.289  
## SUNY College at Oswego 8092.581  
## SUNY College at Fredonia 7862.156  
## SUNY College at Geneseo 9598.755  
## SUNY College at Potsdam 8070.719  
## SUNY College at Purchase 7908.736  
## Susquehanna University 13083.522  
## Syracuse University 14222.887  
## Talladega College 7628.105  
## Tennessee Wesleyan College 7423.922  
## Texas A&M Univ. at College Station 7858.188  
## Texas Christian University 10108.635  
## Texas Wesleyan University 8644.120  
## Thiel College 10678.322  
## Tiffin University 8862.697  
## Tri-State University 9688.950  
## Trinity College CT 16631.517  
## Trinity College VT 11990.114  
## Tusculum College 8490.527  
## Tuskegee University 9503.514  
## Univ. of Wisconsin at OshKosh 5047.237  
## University of California at Berkeley 12302.666  
## University of Central Florida 6520.107  
## University of Charleston 8629.818  
## University of Chicago 20164.802  
## University of Delaware 11028.408  
## University of Denver 11879.456  
## University of Detroit Mercy 9588.672  
## University of Dubuque 9461.839  
## University of Florida 10127.338  
## University of Hartford 11476.319  
## University of La Verne 10234.991  
## University of Louisville 6820.976  
## University of Maine at Machias 5898.433  
## University of Maryland at Baltimore County 6992.084  
## University of Massachusetts at Amherst 8637.132  
## University of Massachusetts at Dartmouth 8039.498  
## University of Miami 14741.974  
## University of Michigan at Ann Arbor 12198.372  
## University of Minnesota at Morris 7396.530  
## University of Mississippi 7420.730  
## University of Missouri at Rolla 8747.299  
## University of Missouri at Saint Louis 5587.920  
## University of Mobile 7824.145  
## University of Montevallo 6025.390  
## University of New England 10711.952  
## University of New Hampshire 8140.735  
## University of North Carolina at Charlotte 6188.915  
## University of North Carolina at Wilmington 7009.189  
## University of North Dakota 6966.154  
## University of North Florida 7421.004  
## University of North Texas 5263.167  
## University of Northern Iowa 6733.887  
## University of Oklahoma 6913.859  
## University of Oregon 7291.490  
## University of Pennsylvania 19332.814  
## University of Puget Sound 11796.148  
## University of Rochester 17810.885  
## University of San Diego 12904.175  
## University of Scranton 14281.201  
## University of South Carolina at Aiken 4610.727  
## University of South Carolina at Columbia 7158.626  
## University of South Florida 6572.564  
## University of Southern California 14366.381  
## University of Southern Mississippi 6248.171  
## University of St. Thomas TX 10438.009  
## University of Tennessee at Knoxville 6637.975  
## University of Texas at San Antonio 7234.424  
## University of the South 15118.614  
## University of Utah 6548.418  
## University of Washington 9667.053  
## University of Wisconsin-Superior 5607.949  
## University of Wisconsin-Whitewater 5966.085  
## University of Wisconsin at Green Bay 5238.948  
## University of Wisconsin at Madison 9897.087  
## University of Wisconsin at Milwaukee 5080.129  
## University of Wyoming 7048.708  
## Upper Iowa University 8292.643  
## Vanderbilt University 17899.758  
## Virginia Tech 8163.550  
## Virginia Union University 7681.199  
## Virginia Wesleyan College 11026.682  
## Voorhees College 5813.921  
## Wabash College 14194.355  
## Wagner College 11806.940  
## Walsh University 10283.262  
## Warren Wilson College 9492.474  
## Wartburg College 11222.641  
## Washington and Jefferson College 13090.578  
## Washington College 13480.850  
## Wayne State College 5099.039  
## Wellesley College 18119.079  
## Wentworth Institute of Technology 11303.236  
## Wesley College 9486.019  
## West Liberty State College 4080.906  
## West Virginia Wesleyan College 10881.622  
## Western Maryland College 12950.907  
## Western Washington University 7273.270  
## Westminster College 11397.284  
## Westmont College 10087.849  
## Wheaton College IL 13212.249  
## Westminster College PA 16072.962  
## Wheeling Jesuit College 10928.707  
## Whittier College 12840.988  
## William Jewell College 9025.691  
## William Woods University 8144.840  
## Williams College 18686.027  
## Winona State University 5057.586  
## Wittenberg University 12699.587  
## Wofford College 12623.206  
## Worcester Polytechnic Institute 14294.010  
## Xavier University 12017.801

mean((ridge.pred - College$Outstate[test])^2)

## [1] 4020611

* viewing parameter estimates of ridge regression

coef(ridge)

## 18 x 1 sparse Matrix of class "dgCMatrix"  
## s0  
## (Intercept) -1.174825e+03  
## PrivateYes 2.096440e+03  
## Apps -1.638920e-02  
## Accept 1.391342e-01  
## Enroll -5.331343e-02  
## Top10perc 1.478036e+01  
## Top25perc 9.340120e+00  
## F.Undergrad -4.320066e-02  
## P.Undergrad -5.995280e-02  
## Room.Board 8.823985e-01  
## Books 2.752593e-01  
## Personal -3.731758e-01  
## PhD 1.634417e+01  
## Terminal 1.709070e+01  
## S.F.Ratio -5.079251e+01  
## perc.alumni 4.372456e+01  
## Expend 1.483435e-01  
## Grad.Rate 2.068170e+01

# 3

* need to select the tuning parameter for lasso
* need to perform 10-fold cross-validation with cv.glmnet()

set.seed(1)  
cv.out = cv.glmnet(features[train,], College$Outstate[train], alpha = 1)  
  
# getting the value of lambda yielding the smallest CV error  
bestlam = cv.out$lambda.min  
bestlam

## [1] 83.93351

* performing lasso on training set

lasso = glmnet(x = features[train,], y = College$Outstate[train], aplha = 1, lambda = bestlam)

* calculate the test MSE for the value of lambda yielding the smallest CV error

lasso.pred = predict(lasso, s = bestlam, newx = features[test,])  
mean((lasso.pred - College$Outstate[test])^2)

## [1] 4073819

lasso.pred

## 1  
## Adelphi University 10990.357  
## Alaska Pacific University 8787.242  
## Albright College 12259.902  
## Alderson-Broaddus College 7989.008  
## American International College 10617.712  
## Amherst College 17900.329  
## Anderson University 8627.266  
## Andrews University 8696.448  
## Assumption College 13641.437  
## Augustana College IL 12175.143  
## Augustana College 9688.725  
## Austin College 12593.845  
## Baker University 9249.980  
## Bard College 15493.978  
## Barry University 11159.717  
## Baylor University 11203.412  
## Beaver College 12763.393  
## Bellarmine College 10054.136  
## Belmont University 9295.256  
## Beloit College 11780.093  
## Bemidji State University 4128.418  
## Benedictine College 9367.218  
## Bennington College 11636.647  
## Bethany College 9013.685  
## Bethel College 7616.057  
## Bethune Cookman College 7276.776  
## Bloomsburg Univ. of Pennsylvania 6223.670  
## Bluefield College 8483.335  
## Bluffton College 10204.408  
## Bowling Green State University 6770.802  
## Bradford College 13085.301  
## Bradley University 11165.278  
## Brandeis University 16220.981  
## Brenau University 10938.079  
## Brewton-Parker College 5708.475  
## Bridgewater College 11504.019  
## Brigham Young University at Provo 10595.770  
## Brown University 17551.374  
## Bryn Mawr College 17865.784  
## Cabrini College 12757.748  
## Caldwell College 11196.491  
## California State University at Fresno 7451.806  
## Calvin College 11316.476  
## Campbell University 9034.089  
## Capitol College 7218.056  
## Carnegie Mellon University 16720.704  
## Carson-Newman College 8921.400  
## Castleton State College 7983.691  
## Catawba College 10167.513  
## Cedarville College 10383.621  
## Centenary College 10702.833  
## Center for Creative Studies 11129.336  
## Central College 11006.306  
## Central Connecticut State University 6008.328  
## Chapman University 11945.277  
## Claflin College 7960.862  
## Claremont McKenna College 17504.965  
## Clark University 12928.767  
## Clarke College 10154.899  
## Clemson University 7718.483  
## Clinch Valley Coll. of the Univ. of Virginia 5064.353  
## Coe College 11493.897  
## Coker College 11702.878  
## College Misericordia 12466.644  
## College of Mount St. Vincent 13356.931  
## College of Notre Dame 10593.973  
## College of Saint Elizabeth 12010.059  
## College of Santa Fe 9478.751  
## College of St. Scholastica 10642.505  
## College of the Holy Cross 16783.365  
## College of William and Mary 10584.149  
## Colorado College 14449.524  
## Columbia College 10984.123  
## Concordia College at St. Paul 8973.605  
## Concordia Lutheran College 8324.930  
## Concordia University CA 9815.390  
## Converse College 11328.629  
## D'Youville College 10572.798  
## Dana College 8564.146  
## Daniel Webster College 10340.942  
## Dartmouth College 19812.765  
## Davidson College 16210.913  
## DePauw University 13561.603  
## Dillard University 8767.112  
## Dordt College 8116.094  
## Drew University 15087.064  
## Earlham College 13813.629  
## East Carolina University 6785.218  
## East Tennessee State University 5541.047  
## East Texas Baptist University 6704.025  
## Eastern Connecticut State University 7043.638  
## Elmira College 11607.134  
## Elon College 9927.195  
## Emory University 18599.639  
## Erskine College 11642.009  
## Eureka College 10493.146  
## Evergreen State College 7998.396  
## Fayetteville State University 4450.905  
## Florida Institute of Technology 10470.384  
## Florida International University 6105.869  
## Florida State University 8216.344  
## Fontbonne College 8786.465  
## Fordham University 14064.981  
## Franciscan University of Steubenville 9728.775  
## Furman University 12918.523  
## George Fox College 9408.541  
## George Mason University 7660.970  
## Georgetown College 10481.952  
## Georgetown University 17435.029  
## Georgia Institute of Technology 10831.369  
## Georgia State University 4390.724  
## Georgian Court College 10062.375  
## Goldey Beacom College 5406.375  
## Goshen College 11031.596  
## Greensboro College 9542.246  
## Greenville College 10022.250  
## Grinnell College 16038.365  
## Grove City College 9792.225  
## Guilford College 12123.028  
## Gustavus Adolphus College 12897.716  
## Gwynedd Mercy College 11506.005  
## Hamline University 12350.601  
## Hampton University 8666.947  
## Hardin-Simmons University 7641.876  
## Hartwick College 12668.430  
## Harvey Mudd College 18961.410  
## Hobart and William Smith Colleges 14949.734  
## Hood College 14400.638  
## Hope College 12160.829  
## Husson College 7758.066  
## Illinois Institute of Technology 12585.573  
## Illinois State University 5837.030  
## Illinois Wesleyan University 12568.863  
## Immaculata College 11523.569  
## Indiana State University 5520.170  
## Iona College 12485.362  
## Iowa State University 7333.239  
## Ithaca College 13134.846  
## James Madison University 9349.568  
## Jamestown College 7571.140  
## Jersey City State College 6590.876  
## John Carroll University 13261.327  
## Johns Hopkins University 24609.771  
## Johnson State College 7262.465  
## Judson College 9626.283  
## Juniata College 13481.342  
## Kansas State University 6334.897  
## Kansas Wesleyan University 8280.857  
## Kenyon College 13860.258  
## Keuka College 11421.547  
## King College 9349.516  
## Knox College 13104.519  
## La Salle University 11686.558  
## Lafayette College 15464.417  
## Lawrence University 13877.557  
## Le Moyne College 12740.676  
## Lebanon Valley College 12183.813  
## Lehigh University 15749.134  
## Livingstone College 10190.195  
## Longwood College 6885.380  
## Loras College 9861.766  
## Louisiana Tech University 4325.813  
## Loyola College 13869.623  
## Loyola Marymount University 13234.763  
## Loyola University 12440.647  
## Lycoming College 11177.104  
## Lynchburg College 11376.048  
## Lyndon State College 6839.886  
## MacMurray College 10025.973  
## Malone College 7884.280  
## Manhattan College 14239.569  
## Mankato State University 4749.486  
## Marian College of Fond du Lac 7807.947  
## Marietta College 12221.366  
## Marist College 12706.735  
## Marquette University 12360.239  
## Mary Washington College 9057.829  
## Marymount College Tarrytown 13724.707  
## Maryville College 11429.846  
## Marywood College 11301.122  
## Mayville State University 4396.847  
## McMurry University 7766.152  
## Meredith College 10274.397  
## Mesa State College 4546.070  
## Messiah College 12194.544  
## Michigan State University 8698.982  
## Michigan Technological University 8352.193  
## Millsaps College 12275.434  
## Milwaukee School of Engineering 8386.470  
## Mississippi State University 6229.741  
## Mississippi University for Women 3986.072  
## Monmouth College 10984.515  
## Montana College of Mineral Sci. & Tech. 7508.642  
## Moorhead State University 5575.875  
## Moravian College 12179.361  
## Morris College 7764.532  
## Mount Mary College 8720.518  
## Mount Mercy College 8719.874  
## Mount Vernon Nazarene College 8030.210  
## National-Louis University 9738.896  
## New Jersey Institute of Technology 10423.960  
## New Mexico Institute of Mining and Tech. 7167.862  
## North Carolina State University at Raleigh 11404.228  
## North Central College 14553.342  
## North Dakota State University 5683.878  
## North Park College 11408.603  
## Northern Illinois University 5829.830  
## Northwest Missouri State University 5442.151  
## Northwest Nazarene College 8245.621  
## Oakland University 7394.337  
## Ohio Wesleyan University 14271.406  
## Oklahoma Christian University 7429.310  
## Oklahoma State University 6077.920  
## Otterbein College 11523.305  
## Ouachita Baptist University 8138.203  
## Our Lady of the Lake University 8723.700  
## Pace University 12002.539  
## Pacific Lutheran University 11651.191  
## Pacific Union College 9454.460  
## Pembroke State University 4877.255  
## Pepperdine University 15761.109  
## Philadelphia Coll. of Textiles and Sci. 10473.979  
## Phillips University 9311.422  
## Pitzer College 14216.588  
## Point Loma Nazarene College 9991.179  
## Point Park College 10010.246  
## Providence College 13559.909  
## Purdue University at West Lafayette 8569.703  
## Quincy University 10949.902  
## Radford University 6653.786  
## Randolph-Macon College 11669.657  
## Randolph-Macon Woman's College 14878.124  
## Regis College 14015.532  
## Rhodes College 14403.648  
## Rider University 12021.567  
## Rollins College 13115.340  
## Rutgers State University at Newark 9168.822  
## Sacred Heart University 11964.723  
## Saint Cloud State University 4572.767  
## Saint Francis College 10884.715  
## Saint Joseph's College IN 9763.031  
## Saint Joseph's College 10113.051  
## Saint Mary's College 12731.113  
## Saint Mary's College of Minnesota 9219.953  
## Salisbury State University 7406.925  
## Scripps College 17837.191  
## Seattle University 11707.665  
## Seton Hall University 12902.598  
## Seton Hill College 11329.885  
## Shorter College 9024.577  
## Simmons College 15169.429  
## Simpson College 11681.448  
## Skidmore College 14862.339  
## South Dakota State University 5050.162  
## Southeast Missouri State University 5483.679  
## Southeastern Oklahoma State Univ. 4341.757  
## Southern California College 8779.116  
## Southwest State University 5699.702  
## Southwestern University 13258.685  
## Spalding University 9474.434  
## Spelman College 12133.381  
## St. John's College 13236.614  
## St. John Fisher College 12496.381  
## St. Mary's College of California 13540.239  
## St. Mary's College of Maryland 9558.611  
## St. Mary's University of San Antonio 9720.214  
## St. Norbert College 12065.361  
## St. Thomas Aquinas College 10653.196  
## Stephens College 10361.623  
## Stetson University 12105.529  
## Stockton College of New Jersey 7364.138  
## SUNY at Binghamton 9648.918  
## SUNY at Stony Brook 9586.224  
## SUNY College at Oswego 8101.693  
## SUNY College at Fredonia 7538.897  
## SUNY College at Geneseo 8895.039  
## SUNY College at Potsdam 7748.149  
## SUNY College at Purchase 7602.150  
## Susquehanna University 13138.486  
## Syracuse University 14457.821  
## Talladega College 7378.692  
## Tennessee Wesleyan College 7479.406  
## Texas A&M Univ. at College Station 8500.386  
## Texas Christian University 10088.035  
## Texas Wesleyan University 8684.794  
## Thiel College 10705.187  
## Tiffin University 9154.964  
## Tri-State University 9792.228  
## Trinity College CT 16684.673  
## Trinity College VT 12041.979  
## Tusculum College 8813.176  
## Tuskegee University 9480.790  
## Univ. of Wisconsin at OshKosh 4969.497  
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## University of Charleston 8201.836  
## University of Chicago 20568.535  
## University of Delaware 11375.441  
## University of Denver 12106.869  
## University of Detroit Mercy 9830.428  
## University of Dubuque 9661.575  
## University of Florida 10236.730  
## University of Hartford 11665.764  
## University of La Verne 10607.661  
## University of Louisville 6932.761  
## University of Maine at Machias 5464.353  
## University of Maryland at Baltimore County 7012.420  
## University of Massachusetts at Amherst 8356.625  
## University of Massachusetts at Dartmouth 7862.300  
## University of Miami 14782.917  
## University of Michigan at Ann Arbor 11778.429  
## University of Minnesota at Morris 6628.716  
## University of Mississippi 7233.411  
## University of Missouri at Rolla 8143.430  
## University of Missouri at Saint Louis 5624.404  
## University of Mobile 7943.635  
## University of Montevallo 5772.350  
## University of New England 10752.453  
## University of New Hampshire 7801.796  
## University of North Carolina at Charlotte 6001.222  
## University of North Carolina at Wilmington 6853.015  
## University of North Dakota 6830.933  
## University of North Florida 7199.091  
## University of North Texas 5764.289  
## University of Northern Iowa 6611.175  
## University of Oklahoma 6803.248  
## University of Oregon 7164.938  
## University of Pennsylvania 19569.058  
## University of Puget Sound 11667.639  
## University of Rochester 17834.559  
## University of San Diego 13026.279  
## University of Scranton 14356.139  
## University of South Carolina at Aiken 4252.149  
## University of South Carolina at Columbia 7145.416  
## University of South Florida 7090.701  
## University of Southern California 14651.482  
## University of Southern Mississippi 6093.410  
## University of St. Thomas TX 10219.342  
## University of Tennessee at Knoxville 6782.163  
## University of Texas at San Antonio 7690.862  
## University of the South 15112.959  
## University of Utah 6693.315  
## University of Washington 9819.141  
## University of Wisconsin-Superior 5193.309  
## University of Wisconsin-Whitewater 5932.401  
## University of Wisconsin at Green Bay 5075.908  
## University of Wisconsin at Madison 9783.731  
## University of Wisconsin at Milwaukee 5299.471  
## University of Wyoming 6886.477  
## Upper Iowa University 8368.209  
## Vanderbilt University 17767.799  
## Virginia Tech 7664.157  
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## Virginia Wesleyan College 11166.989  
## Voorhees College 6143.995  
## Wabash College 14112.739  
## Wagner College 12088.084  
## Walsh University 10181.033  
## Warren Wilson College 9365.717  
## Wartburg College 11010.632  
## Washington and Jefferson College 12867.836  
## Washington College 13424.680  
## Wayne State College 4964.527  
## Wellesley College 18116.940  
## Wentworth Institute of Technology 12081.229  
## Wesley College 9661.991  
## West Liberty State College 3735.839  
## West Virginia Wesleyan College 10951.210  
## Western Maryland College 12997.772  
## Western Washington University 7327.461  
## Westminster College 11290.739  
## Westmont College 9669.874  
## Wheaton College IL 13077.814  
## Westminster College PA 16611.464  
## Wheeling Jesuit College 10988.217  
## Whittier College 13033.090  
## William Jewell College 8844.081  
## William Woods University 8394.681  
## Williams College 18655.928  
## Winona State University 5008.270  
## Wittenberg University 12535.078  
## Wofford College 12393.020  
## Worcester Polytechnic Institute 14217.877  
## Xavier University 12127.569

* using coef() to see if any features have been removed

coef(lasso)

## 18 x 1 sparse Matrix of class "dgCMatrix"  
## s0  
## (Intercept) -2.320041e+03  
## PrivateYes 2.535114e+03  
## Apps .   
## Accept 3.559634e-02  
## Enroll .   
## Top10perc 6.356789e+00  
## Top25perc 9.301472e+00  
## F.Undergrad .   
## P.Undergrad -2.425595e-02  
## Room.Board 9.729620e-01  
## Books .   
## Personal -3.096612e-01  
## PhD 1.501343e+01  
## Terminal 1.510252e+01  
## S.F.Ratio -7.724549e+00  
## perc.alumni 4.526925e+01  
## Expend 1.842542e-01  
## Grad.Rate 1.956816e+01