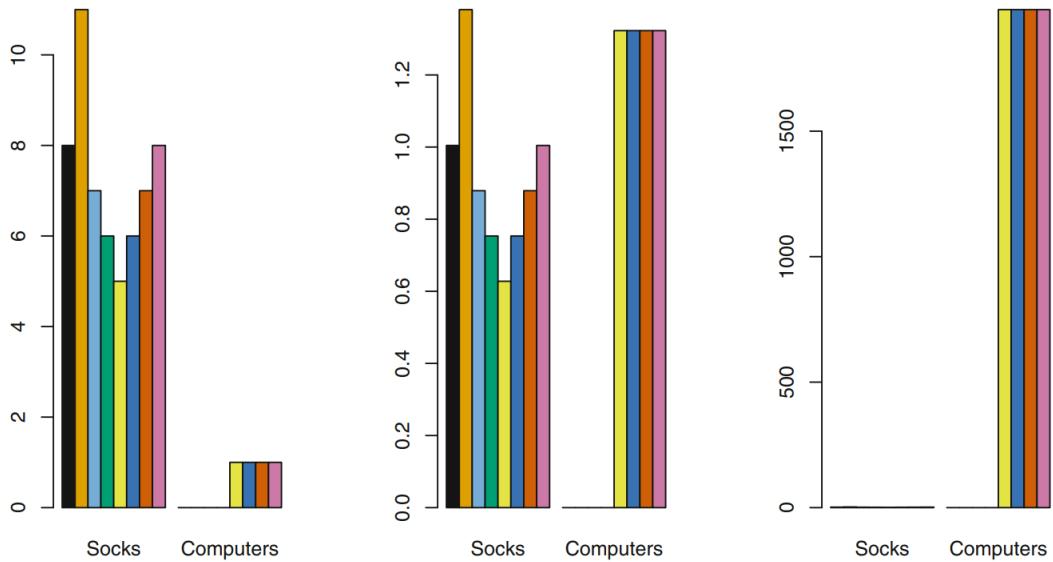


Assignment 6

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October 23, 2025

Exercise 5



First Graph

Since the difference in computers between any two customers is at most 1 in this graph, (which is small compared to difference in socks), it plays almost no role in the grouping of the customers. Thus, a $K = 2$ clustering here is essentially just considering the socks axis, which is mainly grouped into one cluster around the 7 socks mark (so black, pink, cyan, red, green, blue, and yellow) and one outlier at 11 socks (orange).

Second Graph

When scaling by the standard deviation, all values get transformed to relatively the same scale, meaning that the number of computers bought has a weight in determining the clusters. In this case, the difference in computers is around 1.3, which is quite large compared to differences in socks. Therefore, we would expect the clusters to be based around the computers - where black, orange, cyan, and green are in one cluster, and yellow, blue, red, and pink are in another.

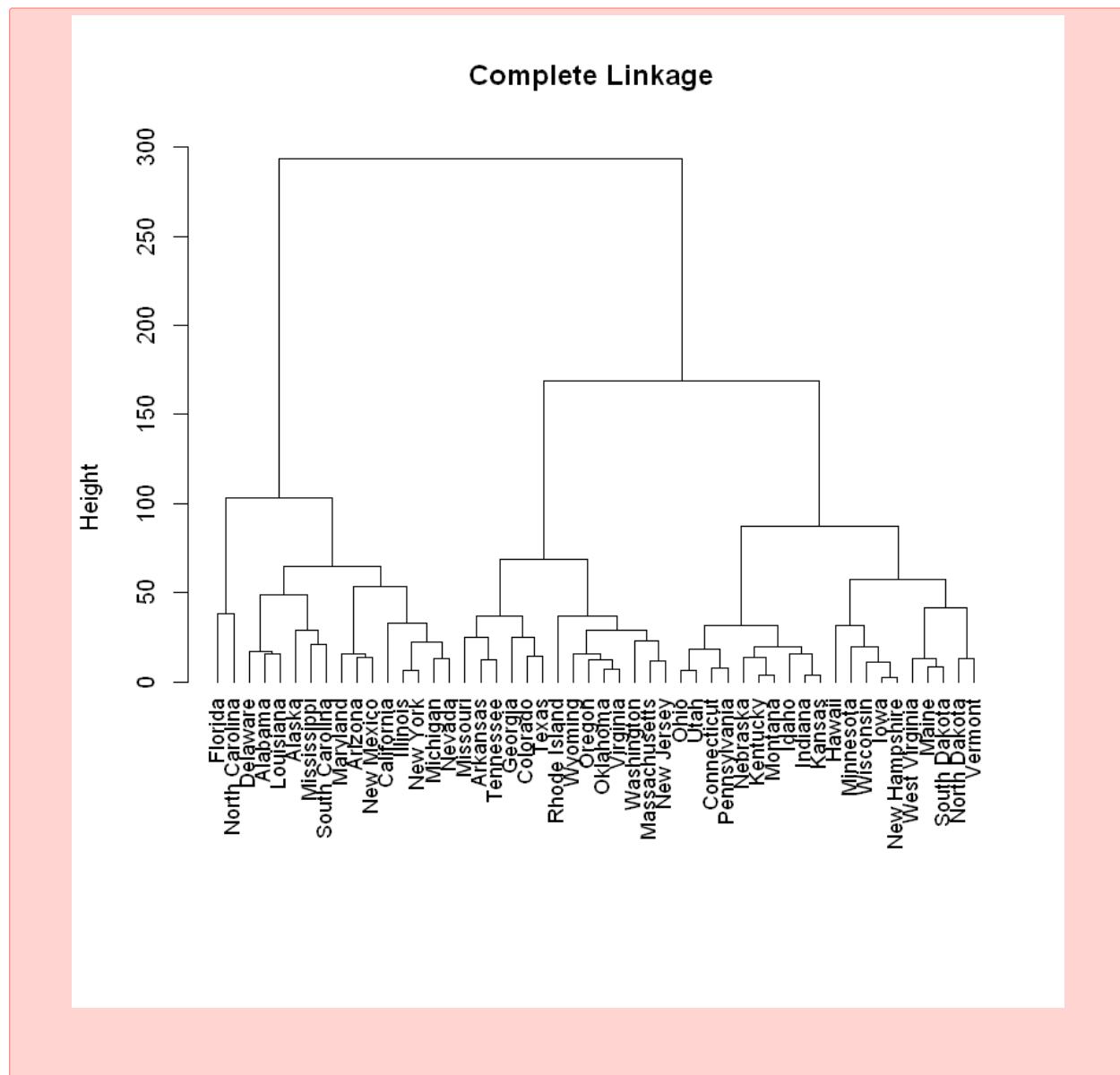
Third Graph

In this case, socks are insignificant, and we simply group by computers. This results in the same grouping as above - black, orange, cyan, and green are in one cluster, and yellow, blue, red, and pink are in another.

Exercise 9

Part (a)

```
[1]: hcl = hclust(dist(USArrests), method="complete")
plot(hcl ,main="Complete Linkage ", xlab="", sub="", cex=.9, hang=-1)
```



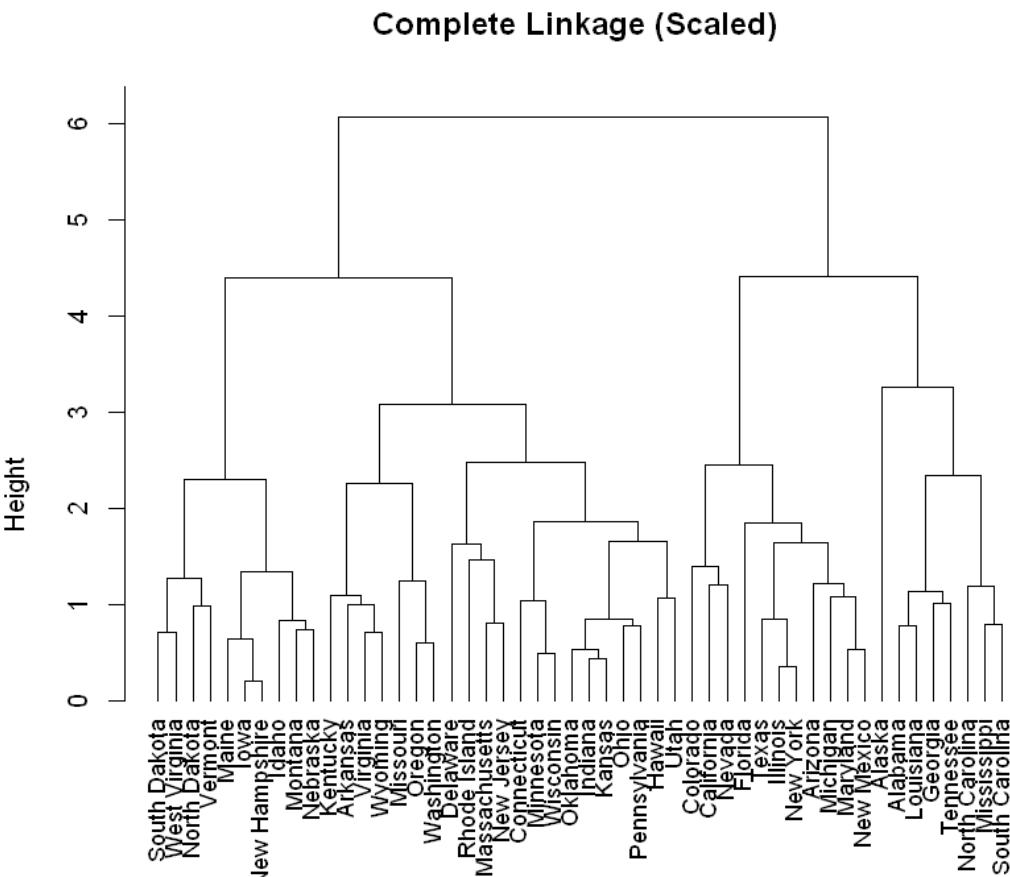
Part (b)

```
[15]: print(cutree(hcl,3))
```

	Alabama	Alaska	Arizona	Arkansas	California
1		1	2	3	2
Colorado	Connecticut		Delaware	Florida	Georgia
2		3		2	1
Hawaii	Idaho		Illinois	Indiana	Iowa
3		3		3	3
Kansas	Kentucky		Louisiana	Maine	Maryland
3		3		3	2
Massachusetts	Michigan		Minnesota	Mississippi	Missouri
3		2		1	3
Montana	Nebraska		Nevada	New Hampshire	New Jersey
3		3		3	3
New Mexico	New York	North Carolina		North Dakota	Ohio
2		2		3	3
Oklahoma	Oregon	Pennsylvania	Rhode Island	South Carolina	
3		3		3	1
South Dakota	Tennessee	Texas		Utah	Vermont
3		1		3	3
Virginia	Washington	West Virginia		Wisconsin	Wyoming
3		3		3	3

Part (c)

```
[3]: US.scale = scale(USArrests)
hcl = hclust(dist(US.scale), method="complete")
plot(hcl, main="Complete Linkage (Scaled) ", xlab="", sub="", cex=.9, hang=-1)
```



```
[17]: print(cutree(hcl,3))
```

	Alabama	Alaska	Arizona	Arkansas	California
1		1	2	3	2
Colorado	Connecticut		Delaware	Florida	Georgia
2		3		2	1
Hawaii	Idaho		Illinois	Indiana	Iowa
3		3		3	3
Kansas	Kentucky		Louisiana	Maine	Maryland
3		3		3	2
Massachusetts	Michigan		Minnesota	Mississippi	Missouri
3		2		1	3
Montana	Nebraska		Nevada	New Hampshire	New Jersey
3		3		3	3

New Mexico	New York	North Carolina	North Dakota	Ohio
2	2	1	3	3
Oklahoma	Oregon	Pennsylvania	Rhode Island	South Carolina
3	3	3	3	1
South Dakota	Tennessee	Texas	Utah	Vermont
3	1	2	3	3
Virginia	Washington	West Virginia	Wisconsin	Wyoming
3	3	3	3	3

Part (d)

Scaling the variables ensures that each variable is represented equally when considering the clustering of the data. This is similar to the previous exercise, where computers and socks were on completely different scales resulting in clustering that was biased towards one variable. Scaling helps adjust the magnitudes of the variables so that the clustering is evenly considered among all the variables. Variables should be scaled before computing inter-observation dissimilarities.

Exercise 10

Part (a)

```
[79]: K = 3 # Generate 3 clusters
obs_clusters = 20 # 20 observations per cluster
var = 50 # 50 variables

centers = as.data.frame(matrix(runif(K * var), nrow = K, ncol = var)) # Generate
# a data frame of three 50-d points for the centers of the clusters
```

```
[92]: data = as.data.frame(matrix(0, nrow = K*obs_clusters, ncol = var + 1)) #
# Generate a blank matrix representing observations
for (i in 1:var) {
  point = c()
  for (j in 1:K) {
    point = c(point, rnorm(obs_clusters, centers[j, i], 0.5)) # For every
    # variable, generate 20 normally distributed points for each cluster with std. dev
    # = 0.5
  }
  data[,i] = point
}
data[,var+1] = rep(1:K,rep(obs_clusters,K)) # Store the actual clusters assigned
# in the last column
```

Part (b)

```
[100]: library(ggplot2)

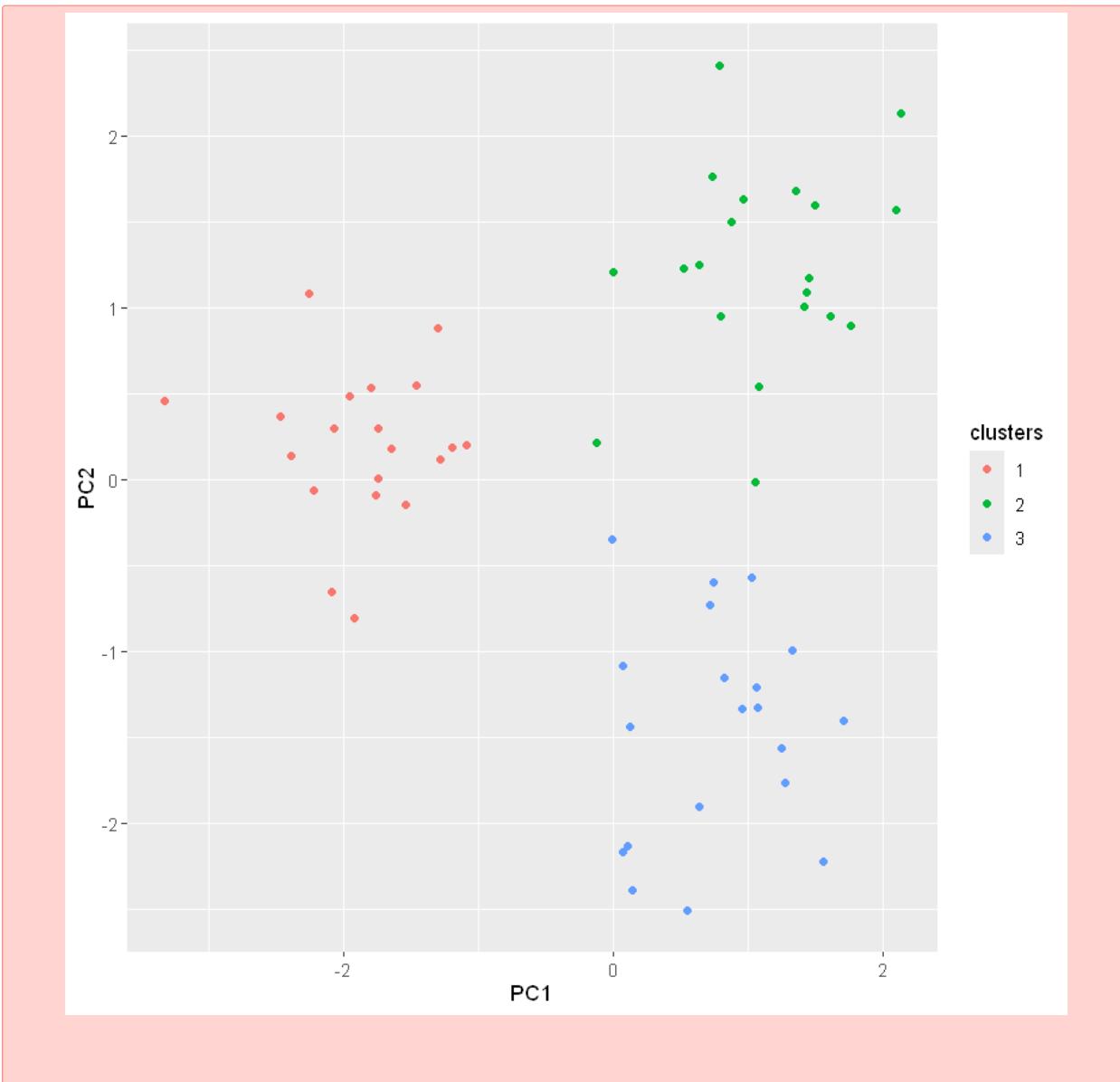
points = data[,-(var+1)] # exclude column with actual labels
```

```
pca = prcomp(points)
PC1 = pca$x[,1]
PC2 = pca$x[,2]

clusters = as.factor(data[,51])

ggplot(points, aes(x=PC1, y=PC2, col=clusters)) + geom_point()

pcldata = data.frame(x=PC1, y=PC2)
```



We can easily see 3 clusters here!

Part (c)

```
[101]: km.out = kmeans(points,K, nstart =1000)
table(data[, (var+1)], km.out$cluster)
```

	1	2	3
1	0	0	20
2	0	20	0
3	20	0	0

The K-means clustering on the raw data has 100% accuracy!

Part (d)

```
[102]: km.out = kmeans(points,K-1, nstart =1000)
table(data[, (var+1)], km.out$cluster)
```

	1	2
1	0	20
2	20	0
3	20	0

When using $K = 2$, the clusters corresponding to 2 and 3 get combined, but all the points in cluster 1 get assigned to label 1.

Part (e)

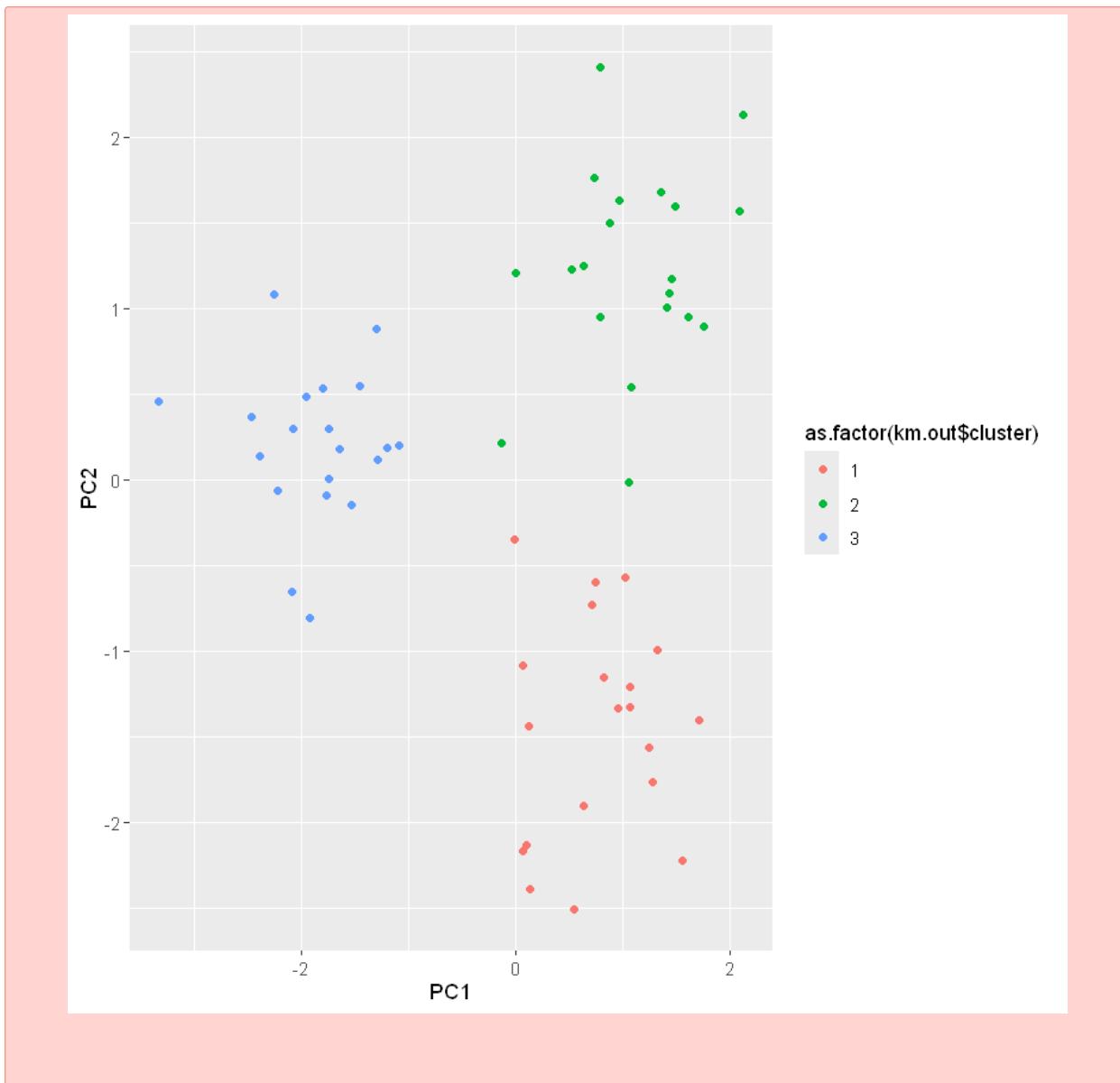
```
[103]: km.out = kmeans(points,K+1, nstart =1000)
table(data[, (var+1)], km.out$cluster)
```

	1	2	3	4
1	0	0	0	20
2	18	0	2	0
3	0	11	9	0

All cluster 1 gets assigned label 4. Most of cluster 2 gets assigned label 2, with some getting assigned label 3 (which is expected as the number of actual clusters is less than the number of labels). Around half of cluster 3 gets assigned to label 1 and around half get assigned to label 3.

Part (f)

```
[104]: km.out = kmeans(pcdata,K, nstart=1000)
ggplot(data, aes(x=PC1, y=PC2, col=as.factor(km.out$cluster))) + geom_point()
```



```
[105]: table(data[, (var+1)], km.out$cluster)
```

	1	2	3
1	0	0	20
2	0	20	0
3	20	0	0

The K-means on the PCA also results in 100% accuracy which is pretty good considering we flattened 48 dimensions!

Part (g)

```
[106]: points.scale = scale(points)
km.out = kmeans(points.scale,K, nstart =1000)
table(data[, (var+1)], km.out$cluster)
```

	1	2	3
1	20	0	0
2	0	1	19
3	0	20	0

Scaling the data actually resulted in 1 error (98.3% accuracy), which makes sense because points that were clearly further apart in the original data get scaled to be closer - so you would expect some overlap between the labels.