1)

a)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> Auto$gas_median=0
> Auto$gas_median[mpg>median(mpg)]=1
>
```

b)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> set.seed(1)
> tune.out=tune(svm,gas_median~.,data=Auto,kernel="linear",ranges=list(cost=c(0.01,0.1,1,5,10,100)))
> summary(tune.out)

Parameter tuning of 'svm':

- sampling method: 10-fold cross validation

- best parameters:
 cost
    1

- best performance: 0.01275641

- Detailed performance results:
   cost      error dispersion
1 1e-02 0.07403846 0.05471525
2 1e-01 0.03826923 0.05148114
3 1e+00 0.01275641 0.01344780
4 5e+00 0.01782051 0.01229997
5 1e+01 0.02038462 0.01074682
6 1e+02 0.03820513 0.01773427

>
```

The error is the least for the case where cost=1 based on the 10 fold cross validation.

c)

POLYNOMIAL KERNEL:

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> set.seed(1)
> tune.out <- tune(svm, gas_median ~ ., data = Auto, kernel = "polynomial", ranges = list(cost = c(0.01, 0.1, 1, 5, 10
, 100), degree = c(2, 3, 4,5)))
> summary(tune.out)

Parameter tuning of 'svm':

- sampling method: 10-fold cross validation

- best parameters:
 cost degree
  100      2

- best performance: 0.3013462

- Detailed performance results:
    cost degree     error dispersion
1  1e-02      2 0.5611538 0.04344202
2  1e-01      2 0.5611538 0.04344202
3  1e+00      2 0.5611538 0.04344202
4  5e+00      2 0.5611538 0.04344202
5  1e+01      2 0.5382051 0.05829238
6  1e+02      2 0.3013462 0.09040277
7  1e-02      3 0.5611538 0.04344202
8  1e-01      3 0.5611538 0.04344202
9  1e+00      3 0.5611538 0.04344202
10 5e+00      3 0.5611538 0.04344202
11 1e+01      3 0.5611538 0.04344202
12 1e+02      3 0.3322436 0.11140578
13 1e-02      4 0.5611538 0.04344202
14 1e-01      4 0.5611538 0.04344202
```

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
13 1e-02       4 0.5611538 0.04344202
14 1e-01       4 0.5611538 0.04344202
15 1e+00       4 0.5611538 0.04344202
16 5e+00       4 0.5611538 0.04344202
17 1e+01       4 0.5611538 0.04344202
18 1e+02       4 0.5611538 0.04344202
19 1e-02       5 0.5611538 0.04344202
20 1e-01       5 0.5611538 0.04344202
21 1e+00       5 0.5611538 0.04344202
22 5e+00       5 0.5611538 0.04344202
23 1e+01       5 0.5611538 0.04344202
24 1e+02       5 0.5611538 0.04344202

>
```

cost=100, degree=2 has the best result according to the lowest cross validation error for the polynomial kernel.

RADIAL KERNEL:

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> set.seed(1)
> tune.out <- tune(svm, gas_median ~ ., data = Auto, kernel = "radial", ranges = list(cost = c(0.01, 0.1, 1, 5, 10, 10
0), gamma = c(0.5,1,2,3,4)))
> summary(tune.out)

Parameter tuning of 'svm':

- sampling method: 10-fold cross validation

- best parameters:
 cost gamma
    5   0.5

- best performance: 0.04852564

- Detailed performance results:
    cost gamma      error dispersion
1  1e-02   0.5 0.56115385 0.04344202
2  1e-01   0.5 0.07916667 0.05201159
3  1e+00   0.5 0.05365385 0.05470590
4  5e+00   0.5 0.04852564 0.04597747
5  1e+01   0.5 0.04852564 0.04597747
6  1e+02   0.5 0.04852564 0.04597747
7  1e-02   1.0 0.56115385 0.04344202
8  1e-01   1.0 0.56115385 0.04344202
9  1e+00   1.0 0.06634615 0.06187383
10 5e+00   1.0 0.06128205 0.06186124
11 1e+01   1.0 0.06128205 0.06186124
12 1e+02   1.0 0.06128205 0.06186124
13 1e-02   2.0 0.56115385 0.04344202
14 1e-01   2.0 0.56115385 0.04344202
```

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
13 1e-02   2.0 0.56115385 0.04344202
14 1e-01   2.0 0.56115385 0.04344202
15 1e+00   2.0 0.12756410 0.05916990
16 5e+00   2.0 0.11730769 0.05277475
17 1e+01   2.0 0.11730769 0.05277475
18 1e+02   2.0 0.11730769 0.05277475
19 1e-02   3.0 0.56115385 0.04344202
20 1e-01   3.0 0.56115385 0.04344202
21 1e+00   3.0 0.37256410 0.14111555
22 5e+00   3.0 0.35205128 0.14165290
23 1e+01   3.0 0.35205128 0.14165290
24 1e+02   3.0 0.35205128 0.14165290
25 1e-02   4.0 0.56115385 0.04344202
26 1e-01   4.0 0.56115385 0.04344202
27 1e+00   4.0 0.48198718 0.04342861
28 5e+00   4.0 0.47435897 0.05241275
29 1e+01   4.0 0.47435897 0.05241275
30 1e+02   4.0 0.47435897 0.05241275

>
```

For the considered values of cost and gamma, gamma=0.5 and cost=5 gives the least cross validation error for the radial kernel.

2)

a)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> attach(OJ)
> train=sample(1:nrow(OJ),800)
>
```

b)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> svm.fit=svm(Purchase~.,data=OJ,subset=train,kernel="linear",cost=0.01,scale=FALSE)
> summary(svm.fit)

Call:
svm(formula = Purchase ~ ., data = OJ, kernel = "linear", cost = 0.01, subset = train, scale = FALSE)


Parameters:
   SVM-Type:  C-classification
 SVM-Kernel:  linear
       cost:  0.01
      gamma:  0.05555556

Number of Support Vectors:  622

 ( 312 310 )


Number of Classes:  2

Levels:
 CH MM


>
```

Number of support vectors in this case is high = 622, out of which 312 belong to CH and 310 belong to MM in the 800 training values of ‘purchase’.

c)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> pred=predict(svm.fit,newdata=OJ[train,])
> train_purchase=Purchase[train]
> table(pred,train_purchase)
    train_purchase
pred  CH  MM
  CH 482 246
  MM   8  64
>
```

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> pred=predict(svm.fit,newdata=OJ[-train,])
> test_purchase=Purchase[-train]
> table(pred,test_purchase)
    test_purchase
pred  CH  MM
  CH 160  81
  MM   3  26
>
```

Training error=1-0.6825=0.3175

Test error=1-0.68=0.311

d)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> train.OJ=OJ[train,]
> tune.out=tune(svm,Purchase~.,data=train.OJ,kernel="linear",ranges=list(cost=10^seq(-2, 1, by = 0.5)))
> summary(tune.out)

Parameter tuning of 'svm':

- sampling method: 10-fold cross validation

- best parameters:
      cost
 0.3162278

- best performance: 0.1725

- Detailed performance results:
         cost   error dispersion
1  0.01000000 0.17375 0.04875178
2  0.03162278 0.17375 0.04308019
3  0.10000000 0.17500 0.04564355
4  0.31622777 0.17250 0.04594683
5  1.00000000 0.17375 0.04581439
6  3.16227766 0.17250 0.04743416
7 10.00000000 0.17375 0.04059026

>
```

Optimal cost=0.3163,

e)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> bestmod=tune.out$best.model
> pred=predict(bestmod,newdata=OJ[train,])
> train_purchase=Purchase[train]
> table(pred,train_purchase)
    train_purchase
pred  CH  MM
  CH 434  74
  MM  56 236
>
```

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> pred=predict(bestmod,newdata=OJ[-train,])
> test_purchase=Purchase[-train]
> table(pred,test_purchase)
    test_purchase
pred  CH  MM
  CH 142  24
  MM  21  83
>
```

Training error0=1-0.8375=0.1625

Test error=1-0.833=0.167

f)

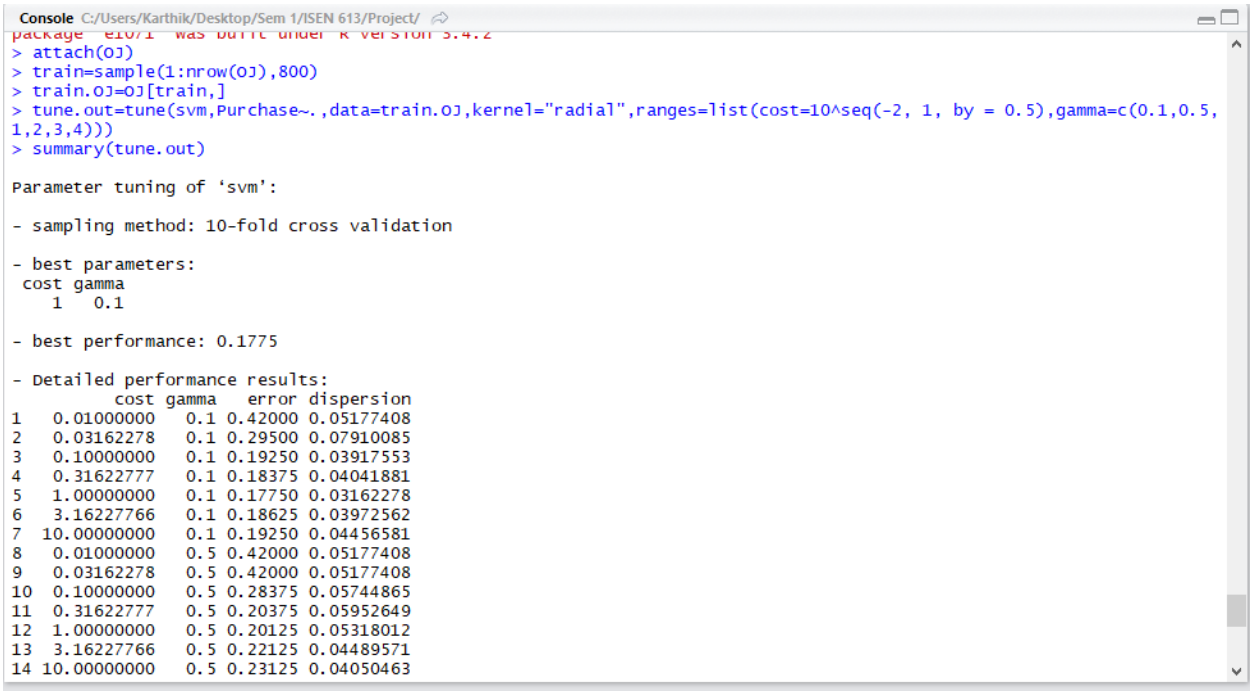
```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> svm.fit=svm(Purchase~.,data=OJ,subset=train,kernel="radial",cost=0.01) #deafault gamma value used
> summary(svm.fit)

Call:
svm(formula = Purchase ~ ., data = OJ, kernel = "radial", cost = 0.01, subset = train)


Parameters:
   SVM-Type:  C-classification
 SVM-Kernel:  radial
       cost:  0.01
      gamma:  0.05555556

Number of Support Vectors:  624

 ( 314 310 )


Number of Classes:  2

Levels:
 CH MM
```

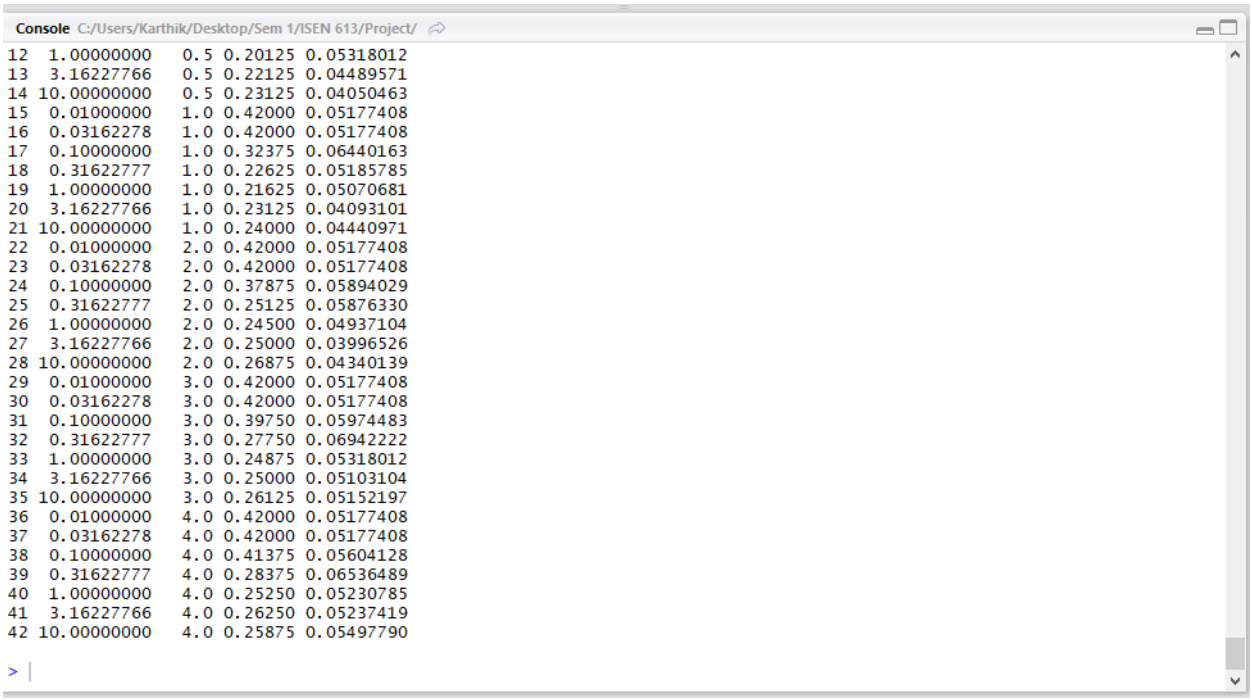
Number of support vectors in this case is high = 624, out of which 314 belong to CH and 310 belong to MM in the 800 training values of 'purchase'.

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
>
> pred=predict(svm.fit,newdata=OJ[train,])
> train_purchase=Purchase[train]
> table(pred,train_purchase)
    train_purchase
pred  CH  MM
  CH 490 310
  MM   0   0
>
>
> pred=predict(svm.fit,newdata=OJ[-train,])
> test_purchase=Purchase[-train]
> table(pred,test_purchase)
    test_purchase
pred  CH  MM
  CH 163 107
  MM   0   0
>
```

Training error=1-0.6125=0.3875

Test error=1-0.604=0.396





Optimal cost=1

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/Project/
> bestmod=tune.out$best.model
> summary(bestmod)

Call:
best.tune(method = svm, train.x = Purchase ~ ., data = train.OJ, ranges = list(cost = 10^seq(-2,
    1, by = 0.5), gamma = c(0.1, 0.5, 1, 2, 3, 4)), kernel = "radial")


Parameters:
   SVM-Type:  C-classification
 SVM-Kernel:  radial
       cost:  1
      gamma:  0.1

Number of Support Vectors:  381

 ( 195 186 )


Number of Classes:  2

Levels:
 CH MM


>
```

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/Project/
> pred=predict(bestmod,newdata=OJ[train,])
> train_purchase=Purchase[train]
> table(pred,train_purchase)
    train_purchase
pred  CH  MM
  CH 415  64
  MM  49 272
>
> pred=predict(bestmod,newdata=OJ[-train,])
> test_purchase=Purchase[-train]
> table(pred,test_purchase)
    test_purchase
pred  CH  MM
  CH 164  27
  MM  25  54
>
```

Training error=1-0.859=0.1413

Test error=1-0.807=0.193

g)

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> svm.fit=svm(Purchase~.,data=OJ,subset=train,kernel="polynomial",cost=0.01) #deafault gamma value used
> summary(svm.fit)

Call:
svm(formula = Purchase ~ ., data = OJ, kernel = "polynomial", cost = 0.01, subset = train)


Parameters:
   SVM-Type:  C-classification
 SVM-Kernel:  polynomial
       cost:  0.01
     degree:  3
      gamma:  0.05555556
     coef.0:  0

Number of Support Vectors:  611

 ( 308 303 )


Number of Classes:  2

Levels:
 CH MM


>
```

Number of support vectors in this case is high = 611, out of which 308 belong to CH and 303 belong to MM in the 800 training values of 'purchase'.

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> pred=predict(svm.fit,newdata=OJ[train,])
> train_purchase=Purchase[train]
> table(pred,train_purchase)
    train_purchase
pred  CH  MM
  CH 486 286
  MM   4  24
>
>
> pred=predict(svm.fit,newdata=OJ[-train,])
> test_purchase=Purchase[-train]
> table(pred,test_purchase)
    test_purchase
pred  CH  MM
  CH 160 102
  MM   3   5
>
```

Training error=1-0.6375=0.3625

Test error=1-0.611=0.389

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> train.OJ=OJ[train,]
> tune.out=tune(svm,Purchase~.,data=train.OJ,kernel="polynomial",ranges=list(cost=10^seq(-2, 1, by = 0.5)),degree=2)
> summary(tune.out)

Parameter tuning of 'svm':

- sampling method: 10-fold cross validation

- best parameters:
 cost
   10

- best performance: 0.185

- Detailed performance results:
         cost   error dispersion
1  0.01000000 0.38750 0.06346478
2  0.03162278 0.35375 0.06375136
3  0.10000000 0.32875 0.05981743
4  0.31622777 0.22000 0.06043821
5  1.00000000 0.20125 0.05756940
6  3.16227766 0.19375 0.05987545
7 10.00000000 0.18500 0.07041543

>
```

Optimal cost=10

```
Console C:/Users/Karthik/Desktop/Sem 1/ISEN 613/
> pred=predict(bestmod,newdata=OJ[train,])
> train_purchase=Purchase[train]
> table(pred,train_purchase)
    train_purchase
pred  CH  MM
  CH 453  87
  MM  37 223
>
> pred=predict(bestmod,newdata=OJ[-train,])
> test_purchase=Purchase[-train]
> table(pred,test_purchase)
    test_purchase
pred  CH  MM
  CH 148  29
  MM  15  78
>
```

Training Error rate= 1-[(457+223)/(453+87+37+223)=0.154

Test error=1-0.837=0.163

h)

	TRAINNIG ERROR	**TEST ERROR**
Linear Kernel	0.1625	0.167
Polynomial Kernel	0.154	0.163
Radial Kernel	0.1413	0.193

According to the test errors, Polynomial Kernel gives the best results and seems to be the most accurate in classifying the 'Purchase' followed closely by the Linear kernel and radial kernel.