Stat 5309 Lab 4b

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1.

The yield of a chemical process is being studied. The two most important variables are thought ot be th pressure and the temperature. Three levels of each factor are selected and a factorial experiment with two replicates is performed. The yield data follows.

a

Set up the dataframe.

```
temperatures <- c("150","160","170")
pressures <- c("200","215","230")
process <- expand.grid(pressure = rep(pressures,2),
                       temperature = temperatures)

process <- cbind(process,yield=c(90.4,90.7,90.2,
                                 90.2,90.6,90.4,
                                 90.1,90.5,89.9,
                                 90.3,90.6,90.1,
                                 90.5,90.8,90.4,
                                 90.7,90.9,90.1))
process %>% kable()
```

pressure	temperature	yield
200	150	90.4
215	150	90.7
230	150	90.2
200	150	90.2
215	150	90.6
230	150	90.4
200	160	90.1
215	160	90.5
230	160	89.9
200	160	90.3
215	160	90.6
230	160	90.1
200	170	90.5
215	170	90.8
230	170	90.4
200	170	90.7
215	170	90.9
230	170	90.1

b

Build a linear model using aov(). Are the pressure means significant? Are the temp means significant? Is the interaction significant?

```
yield_model <- aov(yield ~ temperature * pressure, data=process)
summary(yield_model)
```

```
##                      Df Sum Sq Mean Sq F value   Pr(>F)
## temperature           2 0.3011  0.1506   8.469 0.008539 **
## pressure              2 0.7678  0.3839  21.594 0.000367 ***
## temperature:pressure  4 0.0689  0.0172   0.969 0.470006
## Residuals             9 0.1600  0.0178
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The interaction between temperature and pressure is not significant. The main effects of temperature and pressure are significant.

```
yield_model <- aov(yield ~ temperature + pressure, data=process)
summary(yield_model)
```

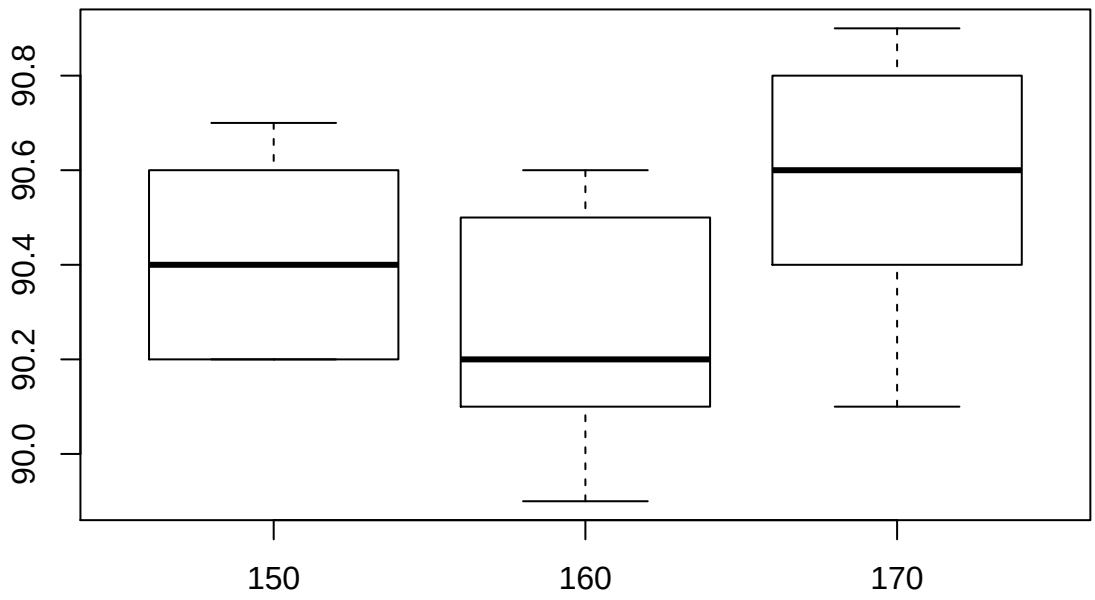
```
##             Df Sum Sq Mean Sq F value   Pr(>F)
## temperature  2 0.3011  0.1506   8.551  0.00426 **
## pressure     2 0.7678  0.3839  21.803 7.03e-05 ***
## Residuals   13 0.2289  0.0176
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

c

Create a boxplot of

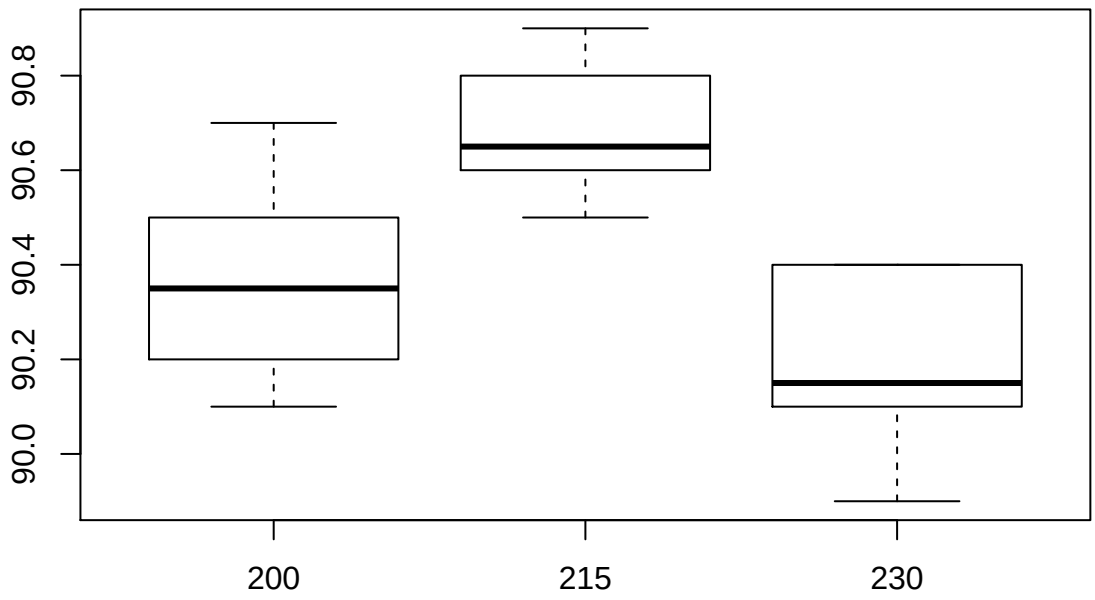
yield vs temp

```
boxplot(yield~temperature, data=process)
```



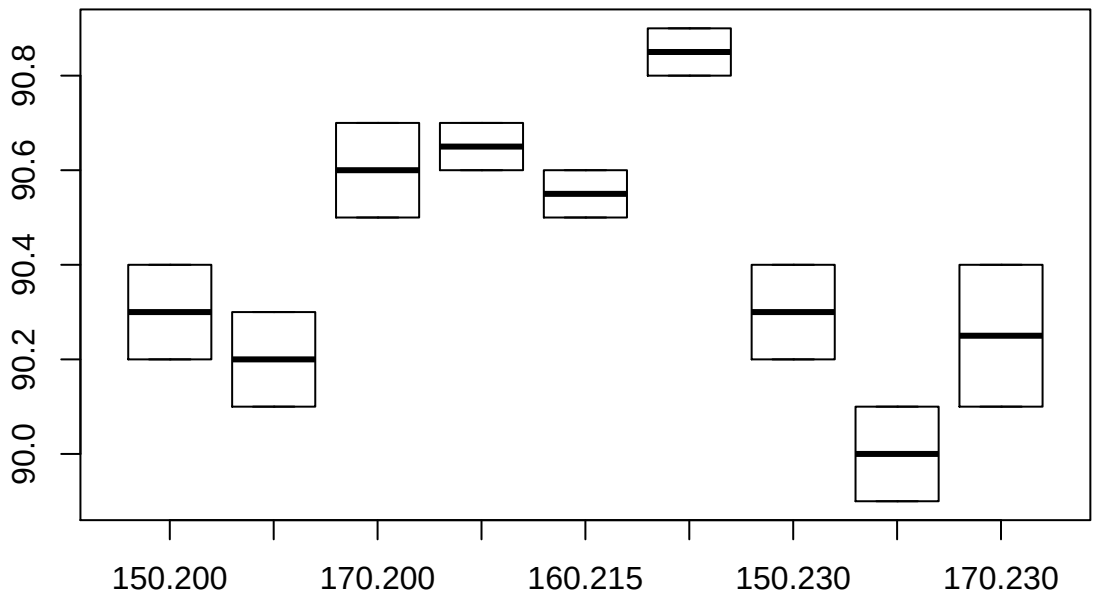
yield vs pressure

```
boxplot(yield~pressure, data=process)
```



yield vs temp and pressure

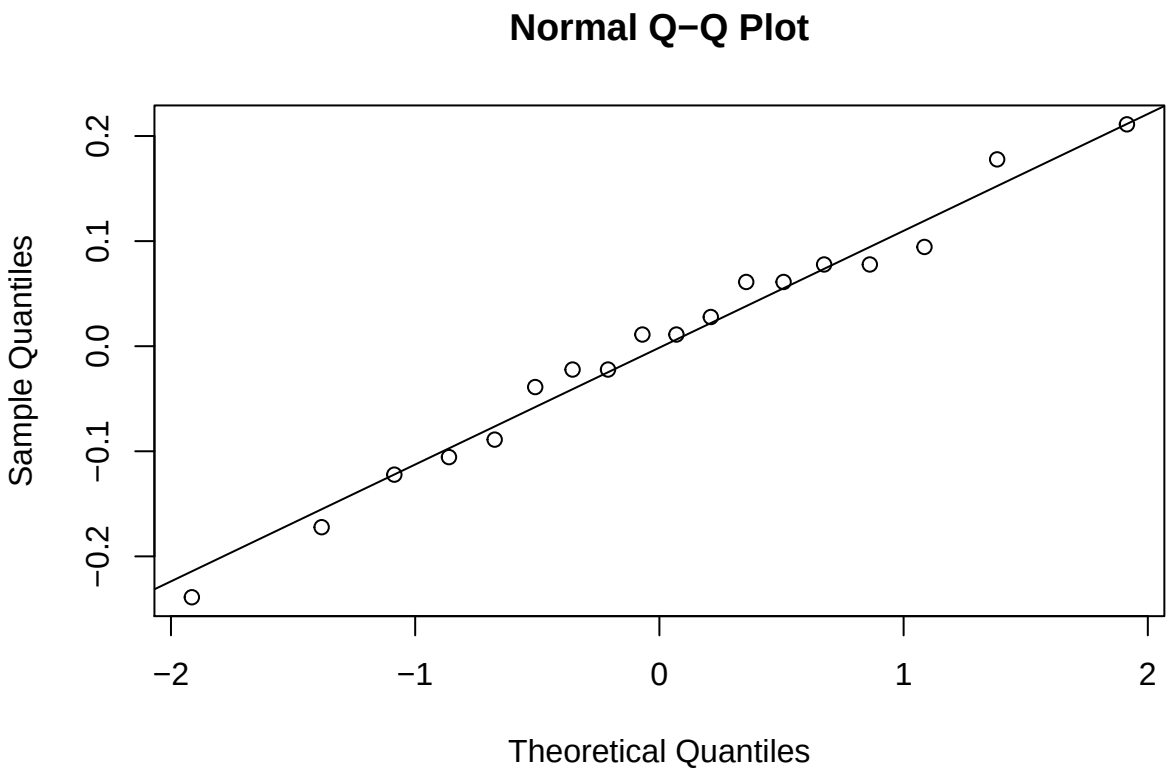
```
boxplot(yield~temperature*pressure, data=process)
```



d

Perform a residuals assumption check

```
qqnorm(yield_model$residuals)
qqline(yield_model$residuals)
```



The residuals are consistent with a normal distribution centered on zero with constant variance.

2

Johnson an dLeone describe an experiment to investigate warping of copper plates. The two factors studied were the temperature and the copper content of the plates. The response variable was a meaure of the amont of warping. The data were as follows.

a

Set up the dataframe

```
temperatures <- c("50","75","100","125")
copper_contents <- c("40","60","80","100")
copperplate <- expand.grid(copper_content=rep(copper_contents,2),
                           temperature=temperatures
                           )
copperplate <- cbind(copperplate,warping = c(17,16,24,28,
                                             20,21,22,27,
                                             12,18,17,12,
                                             9,13,12,31,
                                             16,18,25,30,
                                             12,21,23,23,
                                             21,23,23,29,
```

```
                                          17,21,22,31))
copperplate %>% kable()
```

copper_content	temperature	warping
40	50	17
60	50	16
80	50	24
100	50	28
40	50	20
60	50	21
80	50	22
100	50	27
40	75	12
60	75	18
80	75	17
100	75	12
40	75	9
60	75	13
80	75	12
100	75	31
40	100	16
60	100	18
80	100	25
100	100	30
40	100	12
60	100	21
80	100	23
100	100	23
40	125	21
60	125	23
80	125	23
100	125	29
40	125	17
60	125	21
80	125	22
100	125	31

b

build a response model surface (RSM) with warpage as response, use rsm().

```
temp_nums <- copperplate$temperature %>% as.numeric()
cu_nums <- copperplate$copper_content %>% as.numeric()
response <- copperplate$warping
copper_model<- rsm(response ~ SO(temp_nums, cu_nums), data=copperplate)
summary(copper_model)
```

```
##
## Call:
## rsm(formula = response ~ SO(temp_nums, cu_nums), data = copperplate)
##
##                     Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)        23.68750    6.63925  3.5678 0.001427 **
## temp_nums         -10.33750    3.90821 -2.6451 0.013670 *
## cu_nums             0.57500    3.90821  0.1471 0.884167
## temp_nums:cu_nums   0.16000    0.57274  0.2794 0.782181
## temp_nums^2         2.18750    0.71593  3.0555 0.005142 **
## cu_nums^2           0.50000    0.71593  0.6984 0.491131
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Multiple R-squared:  0.6165, Adjusted R-squared:  0.5427
## F-statistic: 8.358 on 5 and 26 DF,  p-value: 8.125e-05
##
## Analysis of Variance Table
##
## Response: response
##                          Df Sum Sq Mean Sq F value    Pr(>F)
## FO(temp_nums, cu_nums)    2 523.03 261.513 15.9442 3.027e-05
## TWI(temp_nums, cu_nums)   1   1.28   1.280  0.0780    0.7822
## PQ(temp_nums, cu_nums)    2 161.12  80.562  4.9118    0.0155
## Residuals                26 426.45  16.402
## Lack of fit              10 145.44  14.544  0.8282    0.6093
## Pure error               16 281.00  17.563
##
## Stationary point of response surface:
##  temp_nums    cu_nums
##  2.3979170 -0.9586667
##
## Eigenanalysis:
## eigen() decomposition
## $values
## [1] 2.1912841 0.4962159
##
## $vectors
##                  [,1]        [,2]
## temp_nums -0.99888317  0.04724851
## cu_nums   -0.04724851 -0.99888317
```