Math 3080 § 1.	**Bread Wrapper Data:**	Name: Example
Treibergs	2^4 **Incomplete Block Design.**	April 26, 2010

Data File Used in this Analysis:

```
# Math 3080 - 1     Bread Wrapper Data        April 23, 2010
# Treibergs
#
# From Walpole, Myers, Myers, Ye "Probability and Statistics for
# engineers and Scientists. 7th ed.," Prentice Hall 2002
#
# Taken from a VPI study of some more bread wrapper stock.
# This time, an incomplete block design was run. Four factors, A,B,C,D,
# are studied that affect strength Y. The runs were done by two operators
# who each perform different treatment combinations corresponding
# to blocks that correspond to the defining contrast ABC.
#
"Comb"   "Operator"   "Strength"   "A" "B" "C" "D"
(1)   1   18.8   -1   -1   -1   -1
ab    1   16.5    1    1   -1   -1
ac    1   17.8    1   -1    1   -1
bc    1   17.3   -1    1    1   -1
d     1   13.5   -1   -1   -1    1
abd   1   17.6    1    1   -1    1
acd   1   18.5    1   -1    1    1
bcd   1   17.6   -1    1    1    1
a     2   14.7    1   -1   -1   -1
b     2   15.1   -1    1   -1   -1
c     2   14.7   -1   -1    1   -1
abc   2   19.0    1    1    1   -1
ad    2   16.9    1   -1   -1    1
bd    2   17.5   -1    1   -1    1
cd    2   18.2   -1   -1    1    1
abcd  2   20.1    1    1    1    1
```

R Session:

```
R version 2.10.1 (2009-12-14)
Copyright (C) 2009 The R Foundation for Statistical Computing
ISBN 3-900051-07-0

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  Natural language support but running in an English locale

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```

```
Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[R.app GUI 1.31 (5537) powerpc-apple-darwin9.8.0]

> tt <- read.table("M3081DataWrapper.txt",header=TRUE)
> attach(tt)
> tt
   Comb Operator Strength  A  B  C  D
1   (1)        1     18.8 -1 -1 -1 -1
2    ab        1     16.5  1  1 -1 -1
3    ac        1     17.8  1 -1  1 -1
4    bc        1     17.3 -1  1  1 -1
5     d        1     13.5 -1 -1 -1  1
6   abd        1     17.6  1  1 -1  1
7   acd        1     18.5  1 -1  1  1
8   bcd        1     17.6 -1  1  1  1
9     a        2     14.7  1 -1 -1 -1
10    b        2     15.1 -1  1 -1 -1
11    c        2     14.7 -1 -1  1 -1
12  abc        2     19.0  1  1  1 -1
13   ad        2     16.9  1 -1 -1  1
14   bd        2     17.5 -1  1 -1  1
15   cd        2     18.2 -1 -1  1  1
16 abcd        2     20.1  1  1  1  1

>#=======================================RUN ANOVA==============
> f1<-aov(Strength~A*B*C*D);anova(f1)
Analysis of Variance Table

Response: Strength
          Df Sum Sq Mean Sq F value Pr(>F)
A          1 4.4100  4.4100
B          1 3.6100  3.6100
C          1 9.9225  9.9225
D          1 2.2500  2.2500
A:B        1 0.5625  0.5625
A:C        1 2.8900  2.8900
B:C        1 0.2500  0.2500
A:D        1 1.1025  1.1025
B:D        1 0.9025  0.9025
C:D        1 1.6900  1.6900
A:B:C      1 0.1225  0.1225
A:B:D      1 1.6900  1.6900
A:C:D      1 4.2025  4.2025
B:C:D      1 5.5225  5.5225
A:B:C:D    1 9.6100  9.6100
Residuals  0 0.0000
Warning message:
In anova.lm(f1) :
  ANOVA F-tests on an essentially perfect fit are unreliable
```

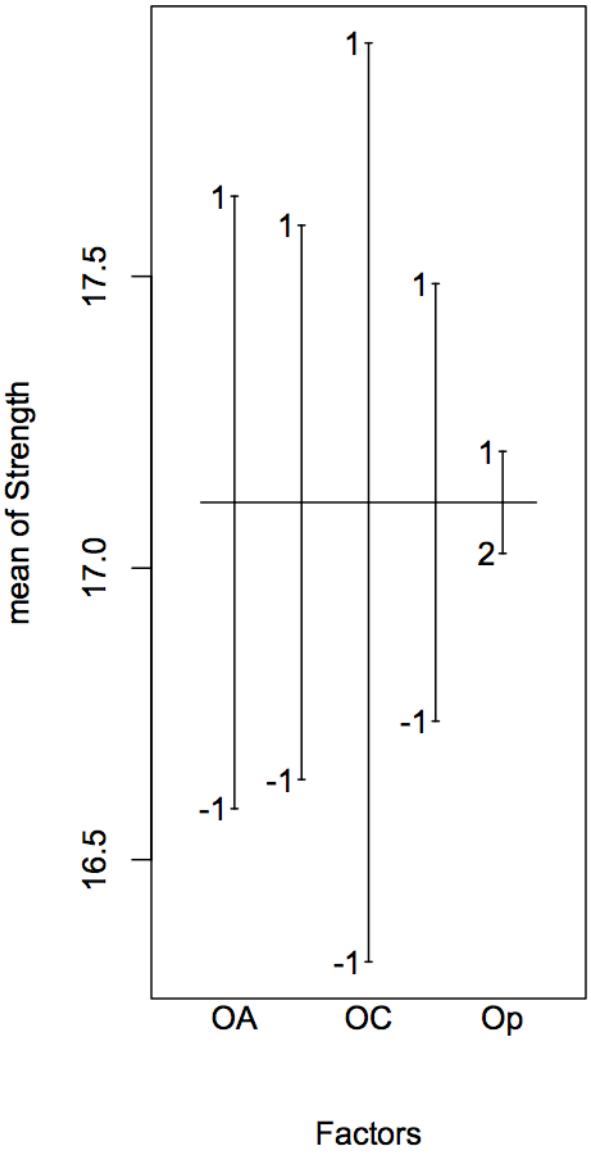
```
>#====================RUN LINEAR MODEL============================
> f2 <- aov(Strength~A+B+C+D+Operator);anova(f2)
Analysis of Variance Table

Response: Strength
          Df  Sum Sq Mean Sq F value  Pr(>F)
A          1  4.4100  4.4100  1.5516 0.24130
B          1  3.6100  3.6100  1.2701 0.28606
C          1  9.9225  9.9225  3.4911 0.09124 .
D          1  2.2500  2.2500  0.7916 0.39451
Operator   1  0.1225  0.1225  0.0431 0.83970
Residuals 10 28.4225  2.8422
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1
> Op<-factor(Operator);OA<-factor(A);OB<-factor(B);OC<-factor(C);OD<-factor(D)


>#==================USUAL DIAGNOSTIC PLOTS=============================

> layout(matrix(1:2,ncol=2))
> plot.design(data.frame(OA,OB,OC,OD,Op,Strength))
> interaction.plot(C,A,Strength)

> layout(matrix(1:4,ncol=2))
> plot(Strength~C,main="Bread Wrapper Data")
> plot(rstandard(f2)~fitted(f2),xlab="Predicted Values", ylab="Standard. Resid.",
  ylim=max(abs(rstandard(f2)))*c(-1,1))
> abline(h=c(0,-2,2),lty=c(2,3,3))
> plot(fitted(f2)~Strength,ylab="Y hat"); abline(0,1)
> qqnorm(rstandard(f2), ylab="Standard. Resid.",
  ylim=max(abs(rstandard(f2)))*c(-1,1))
> abline(h=c(0,-2,2),lty=c(2,3,3)); abline(0,1)
> shapiro.test(resid(f2))

Shapiro-Wilk normality test

data:  resid(f2)
W = 0.9195, p-value = 0.1658
```

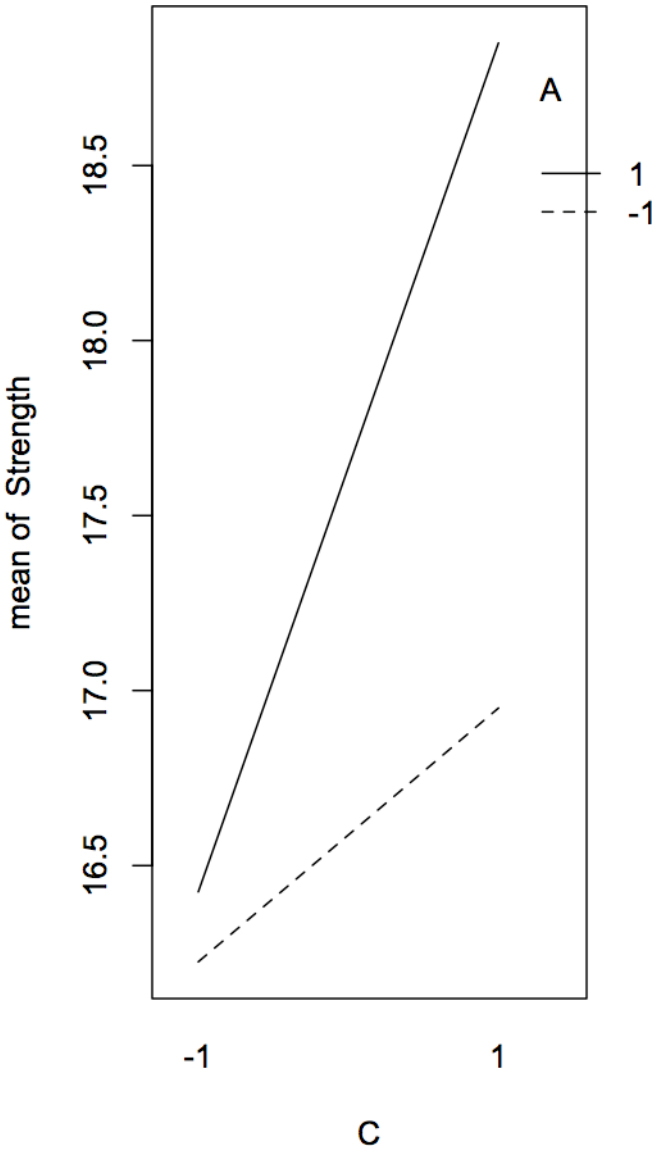
```
>#===================TABLE OF CONTRASTS=======================================
> AB<-A*B;AD<-A*D;AC<-A*C;BC<-B*C;BD<-B*D;CD<-C*D
> ABC<-AB*C;ABD<-AB*D;ACD<-AC*D;BCD<-BC*D;ABCD<-AB*CD
> One<-rep(1,times=16)
> matrix(c(One,A,B,AB,C,AC,BC,ABC,D,AD,BD,ABD,CD,ACD,BCD,ABCD),ncol=16,
  dimnames=list(Comb,Comb))

     (1) ab ac bc  d abd acd bcd  a  b  c abc ad bd cd abcd
(1)    1 -1 -1  1 -1   1   1  -1 -1  1  1  -1  1 -1 -1    1
ab     1  1  1  1 -1  -1  -1  -1 -1 -1 -1  -1  1  1  1    1
ac     1  1 -1 -1  1   1  -1  -1 -1 -1  1   1 -1 -1  1    1
bc     1 -1  1 -1  1  -1   1  -1 -1  1 -1   1 -1  1 -1    1
d      1 -1 -1  1 -1   1   1  -1  1 -1 -1   1 -1  1  1   -1
abd    1  1  1  1 -1  -1  -1  -1  1  1  1   1 -1 -1 -1   -1
acd    1  1 -1 -1  1   1  -1  -1  1  1 -1  -1  1  1 -1   -1
bcd    1 -1  1 -1  1  -1   1  -1  1 -1  1  -1  1 -1  1   -1
a      1  1 -1 -1 -1  -1   1   1 -1 -1  1   1  1  1 -1   -1
b      1 -1  1 -1 -1   1  -1   1 -1  1 -1   1  1 -1  1   -1
c      1 -1 -1  1  1  -1  -1   1 -1  1  1  -1 -1  1  1   -1
abc    1  1  1  1  1   1   1   1 -1 -1 -1  -1 -1 -1 -1   -1
ad     1  1 -1 -1 -1  -1   1   1  1  1 -1  -1 -1 -1  1    1
bd     1 -1  1 -1 -1   1  -1   1  1 -1  1  -1 -1  1 -1    1
cd     1 -1 -1  1  1  -1  -1   1  1 -1 -1   1  1 -1 -1    1
abcd   1  1  1  1  1   1   1   1  1  1  1   1  1  1  1    1

>#============================DEFINING CONTRAST IS ABC THIS TIME============
> matrix(c(Operator,ABC),ncol=2)
      [,1] [,2]
 [1,]    1   -1
 [2,]    1   -1
 [3,]    1   -1
 [4,]    1   -1
 [5,]    1   -1
 [6,]    1   -1
 [7,]    1   -1
 [8,]    1   -1
 [9,]    2    1
[10,]    2    1
[11,]    2    1
[12,]    2    1
[13,]    2    1
[14,]    2    1
[15,]    2    1
[16,]    2    1
```

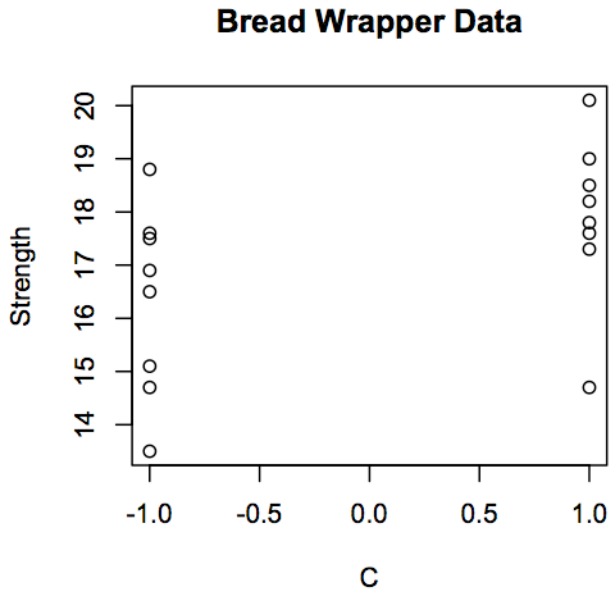
```
>#============================CONTRASTS=======================================
> SST<-sum(Strength*Strength)-(sum(Strength)^2)/16;SST
[1] 48.7375
> LA<-sum(A*Strength)
> LB<-sum(B*Strength)
> LC<-sum(C*Strength)
> LD<-sum(D*Strength)
> LABC<-sum(ABC*Strength)

>#============================BUILD ANOVA TABLE "BY HAND"====================
> DF <- c(1,1,1,1,1,10,15)
> SSA<-LA*LA/16;SSB<-LB*LB/16;SSC<-LC*LC/16;SSD<-LD*LD/16
> SSBlock <- LABC*LABC/16
> SSE<-SST-SSA-SSB-SSC-SSD-SSBlock
> SS<-c(SSA,SSB,SSC,SSD,SSBlock,SSE,SST)
> MSE<-SSE/10
> MS<-c(SSA,SSB,SSC,SSD,SSBlock,MSE,-1)
> F<-MS/MSE;F[7]<--1;F[6]<--1
> P<-pf(F,1,10,lower.tail=FALSE)
> matrix(c(DF,SS,MS,F,P),ncol=5,
  dimnames=list(c("A","B","C","D","Block","Error","Total"), c("DF","SS","MS","F","P(>F)")))


      DF      SS       MS           F      P(>F)
A      1  4.4100  4.41000  1.55158765 0.24129587
B      1  3.6100  3.61000  1.27012050 0.28606043
C      1  9.9225  9.92250  3.49107221 0.09124138
D      1  2.2500  2.25000  0.79162635 0.39450928
Block  1  0.1225  0.12250  0.04309966 0.83970459
Error 10 28.4225  2.84225 -1.00000000 1.00000000
Total 15 48.7375 -1.00000 -1.00000000 1.00000000

>========================================COMPARE TO==========================
> anova(f2)
Analysis of Variance Table

Response: Strength
          Df  Sum Sq Mean Sq F value  Pr(>F)
A          1  4.4100  4.4100  1.5516 0.24130
B          1  3.6100  3.6100  1.2701 0.28606
C          1  9.9225  9.9225  3.4911 0.09124 .
D          1  2.2500  2.2500  0.7916 0.39451
Operator   1  0.1225  0.1225  0.0431 0.83970
Residuals 10 28.4225  2.8422
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1
```

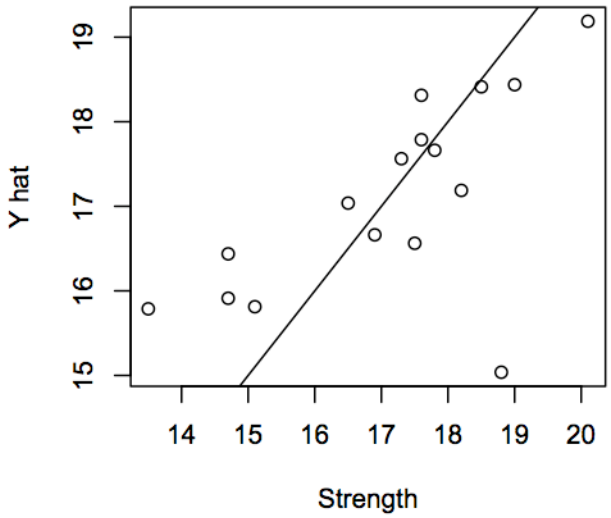
```
>#====================CONTRASTS AND PCT. VARIABILITY FROM EACH FACTOR==============
> EFF<-c(LA/16,LB/16,LC/16,LD/16,LABC/16)
> PCT<-c(SSA,SSB,SSC,SSD,SSBlock)/SST
> matrix(c(EFF,PCT),ncol=2,
  dimnames=list(c("A","B","C","D","Block"), c("Effect","     Fraction Variability")))

       Effect      Fraction Variability
A      0.5250               0.090484740
B      0.4750               0.074070274
C      0.7875               0.203590664
D      0.3750               0.046165684
Block -0.0875               0.002513465

>#=================R SQ, FRACTION OF VARIABILITY ACCOUNTED FOR BY MODEL============
> 1-SSE/SST
[1] 0.4168248

>#==============COMPARE TO SAME MODEL RUN AS REGRESSION============================
> f3<-lm(Strength~A+B+C+D+Operator);summary(f3);anova(f3)
Call:
lm(formula = Strength ~ A + B + C + D + Operator)

Residuals:
    Min      1Q  Median      3Q     Max
-2.2875 -0.7125 -0.0500  0.6500  3.7625

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  17.3750     1.3328  13.036 1.34e-07 ***
A             0.5250     0.4215   1.246   0.2413
B             0.4750     0.4215   1.127   0.2861
C             0.7875     0.4215   1.868   0.0912 .
D             0.3750     0.4215   0.890   0.3945
Operator     -0.1750     0.8429  -0.208   0.8397
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Residual standard error: 1.686 on 10 degrees of freedom
Multiple R-squared: 0.4168,Adjusted R-squared: 0.1252
F-statistic:  1.43 on 5 and 10 DF,  p-value: 0.2943

Analysis of Variance Table

Response: Strength
          Df  Sum Sq Mean Sq F value  Pr(>F)
A          1  4.4100  4.4100  1.5516 0.24130
B          1  3.6100  3.6100  1.2701 0.28606
C          1  9.9225  9.9225  3.4911 0.09124 .
D          1  2.2500  2.2500  0.7916 0.39451
Operator   1  0.1225  0.1225  0.0431 0.83970
Residuals 10 28.4225  2.8422
```

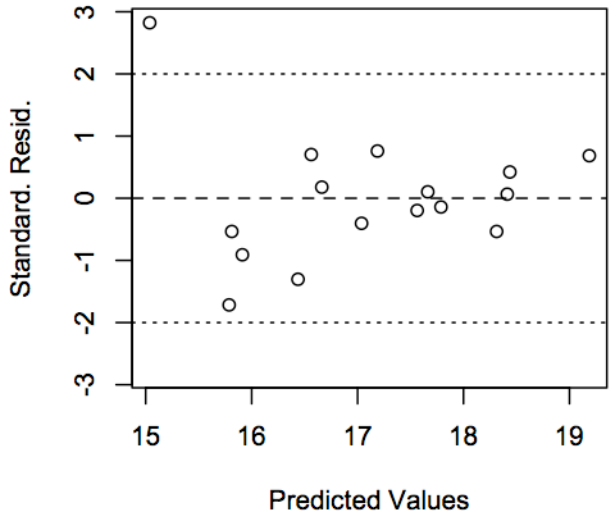
```
> model.tables(f2,"means")
Tables of means
Grand mean

17.1125

 A
A
    -1      1
16.587 17.637

 B
B
    -1      1
16.637 17.587

 C
C
    -1      1
16.325 17.900

 D
D
    -1      1
16.737 17.487

 Operator
Operator
     1      2
17.200 17.025


>#====================FACTORS IN MAIN BLOCK GIVEN BY DEFINING CONTRAST ABC=======
> I<-order(ABC)
> Comb[I[1:8]]
[1] (1) ab  ac  bc  d   abd acd bcd

>#====================FACTORS IN OTHER BLOCK=====================================
> Comb[I[9:16]]
[1] a    b    c    abc  ad   bd   cd   abcd
```

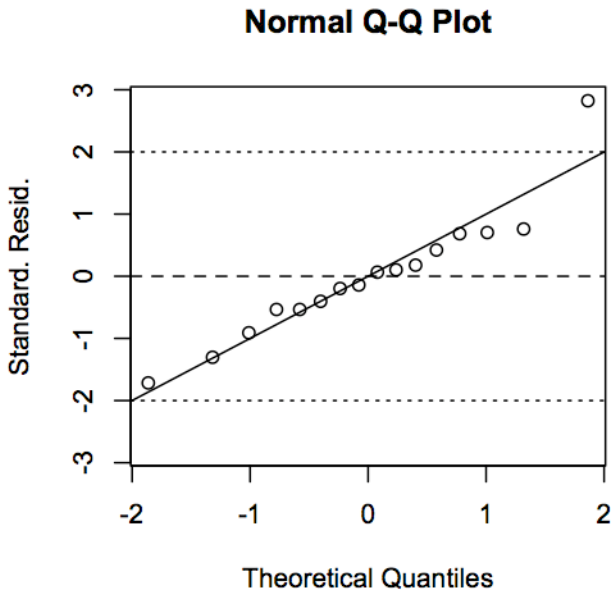

mean of Strength
16.5
17.0
17.5
OA
OC
Op
Factors
1
1
1
1
1
2
-1
-1
-1
-1


mean of Strength
16.5
17.0
17.5
18.0
18.5
-1
1
C
A
1
-1


Bread Wrapper Data
Strength
C
-1.0
-0.5
0.0
0.5
1.0
14
15
16
17
18
19
20


Y hat
Strength
14
15
16
17
18
19
20


Standard. Resid.
Predicted Values
15
16
17
18
19
-3
-2
-1
0
1
2
3


Normal Q-Q Plot
Standard. Resid.
Theoretical Quantiles
-2
-1
0
1
2
-3
-2
-1
0
1
2
3