

# Homework 7

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## 7.21

Given generators  $I = ABCD$ ,  $I = ACE$ ,  $I = ABEF$  we create a dataframe of the factor combinations and produce the aliases below.

```
mtx <- data.matrix(fac.design(2,6))
```

```
## creating full factorial with 64 runs ...
```

```
dx <- scale(mtx, scale=F)  
dx <- sign(dx)  
df <- as.data.frame(dx)
```

Block1	Block2	Block3	Block4	Block5	Block6
<i>ef</i>	<i>ad</i>	<i>acf</i>	<i>bcef</i>	<i>bcd</i> <i>f</i>	<i>c</i> <i>f</i>
<i>ace</i>	<i>bc</i>	<i>bce</i>	<i>cde</i>	<i>be</i>	<i>a</i>
<i>cd</i>	<i>abcde</i>	<i>abef</i>	<i>abcd</i> <i>f</i>	<i>acde</i>	<i>abce</i>
<i>bde</i>	<i>cd</i> <i>f</i>	(1)	<i>ade</i> <i>f</i>	<i>a</i> <i>f</i>	<i>be</i> <i>f</i>
<i>b</i> <i>c</i> <i>f</i>	<i>a</i> <i>b</i> <i>f</i>	<i>b</i> <i>d</i> <i>f</i>	<i>bd</i>	<i>a</i> <i>bd</i>	<i>a</i> <i>cde</i> <i>f</i>
<i>abcde</i> <i>f</i>	<i>a</i> <i>ce</i> <i>f</i>	<i>cde</i> <i>f</i>	<i>ac</i>	<i>de</i> <i>f</i>	<i>a</i> <i>bd</i> <i>f</i>
<i>a</i> <i>d</i> <i>f</i>	<i>bde</i> <i>f</i>	<i>ade</i>	<i>a</i> <i>be</i>	<i>a</i> <i>bce</i> <i>f</i>	<i>bcde</i>
<i>ab</i>	<i>e</i>	<i>a</i> <i>b</i> <i>cd</i>	<i>f</i>	<i>c</i>	<i>de</i>

## 8.11

```
#df <- read_excel("/Users/Earle/Documents/Stats 101B Datasets/CH 8 (P11).xlsx")  
df <- read_excel("~/vmshare/stats 101b datasets/CH 8 (P11).xlsx")
```

**a**

If the design generators are  $I = ACE$  and  $I = BDE$ . Then the individual products of the columns must produce the identity.

```
colnames(df)[1:5] <- c(LETTERS[1:5]);  
df$A*df$C*df$E
```

```
## [1] 1 1 1 1 1 1 1 1
```

```
df$B*df$D*df$E
```

```
## [1] 1 1 1 1 1 1 1 1
```

b

Complete Defining Relation:

$$I = ACE = BDE = ABCD$$

```
g <- lm(Yield ~ (A+B+C+D+E)^5, df)
alias(g)
```

```
## Model :
## Yield ~ (A + B + C + D + E)^5
##
## Complete :
##      (Intercept) A B C D E A:B A:D
## A:E      0      0 0 1 0 0 0 0
## B:C      0      0 0 0 0 0 0 1
## B:D      0      0 0 0 0 1 0 0
## B:E      0      0 0 0 1 0 0 0
## C:D      0      0 0 0 0 0 1 0
## C:E      0      1 0 0 0 0 0 0
## D:E      0      0 1 0 0 0 0 0
## A:B:C    0      0 0 0 1 0 0 0
## A:B:D    0      0 0 1 0 0 0 0
## A:B:E    0      0 0 0 0 0 0 1
## A:C:D    0      0 1 0 0 0 0 0
## A:C:E    1      0 0 0 0 0 0 0
## A:D:E    0      0 0 0 0 0 1 0
## B:C:D    0      1 0 0 0 0 0 0
## B:C:E    0      0 0 0 0 0 1 0
## B:D:E    1      0 0 0 0 0 0 0
## C:D:E    0      0 0 0 0 0 0 1
## A:B:C:D  1      0 0 0 0 0 0 0
## A:B:C:E  0      0 1 0 0 0 0 0
## A:B:D:E  0      1 0 0 0 0 0 0
## A:C:D:E  0      0 0 0 1 0 0 0
## B:C:D:E  0      0 0 1 0 0 0 0
## A:B:C:D:E 0      0 0 0 0 1 0 0
## A:C      0      0 0 0 0 1 0 0
```

<i>Effect</i>	<i>Aliases</i>
<i>A</i>	<i>A + CE + BCD + ABDE</i>
<i>B</i>	<i>B + DE + ACD + ABCE</i>
<i>C</i>	<i>C + AE + ABD + BCDE</i>
<i>D</i>	<i>D + BE + ABC + ACDE</i>
<i>E</i>	<i>E + BD + AC + ABCDE</i>
<i>AB</i>	<i>AB + CD + ADE + BCE</i>
<i>AD</i>	<i>AD + BC + ABE + CDE</i>

c

```
m <- lm(Yield ~ A + B + C + D + E, df)
effects <- 2*m$coefficients[2:6]; effects
```

```
##      A      B      C      D      E
## -1.525 -5.175  2.275 -0.675  2.275
```

d

From both of these ANOVA tables we can see that the sum of the sum of squares for  $AB = 6.661$  and  $AD = 3.251$  are equal to the residual sum of squares 9.913

```
anova(lm(Yield ~ (A + B + C + D + E)^2, df))
```

```
## Warning in anova.lm(lm(Yield ~ (A + B + C + D + E)^2, df)): ANOVA F-tests
## on an essentially perfect fit are unreliable
```

```
## Analysis of Variance Table
##
## Response: Yield
##      Df Sum Sq Mean Sq F value Pr(>F)
## A      1  4.651    4.651    0.9385 0.4349
## B      1 53.561   53.561   10.8068 0.0814 .
## C      1 10.351   10.351    2.0885 0.2853
## D      1  0.911    0.911    0.1839 0.7098
## E      1 10.351   10.351    2.0885 0.2853
## A:B     1  6.661    6.661    1.3568 0.2561
## A:D     1  3.251    3.251    0.6636 0.4241
## Residuals 0  0.000
```

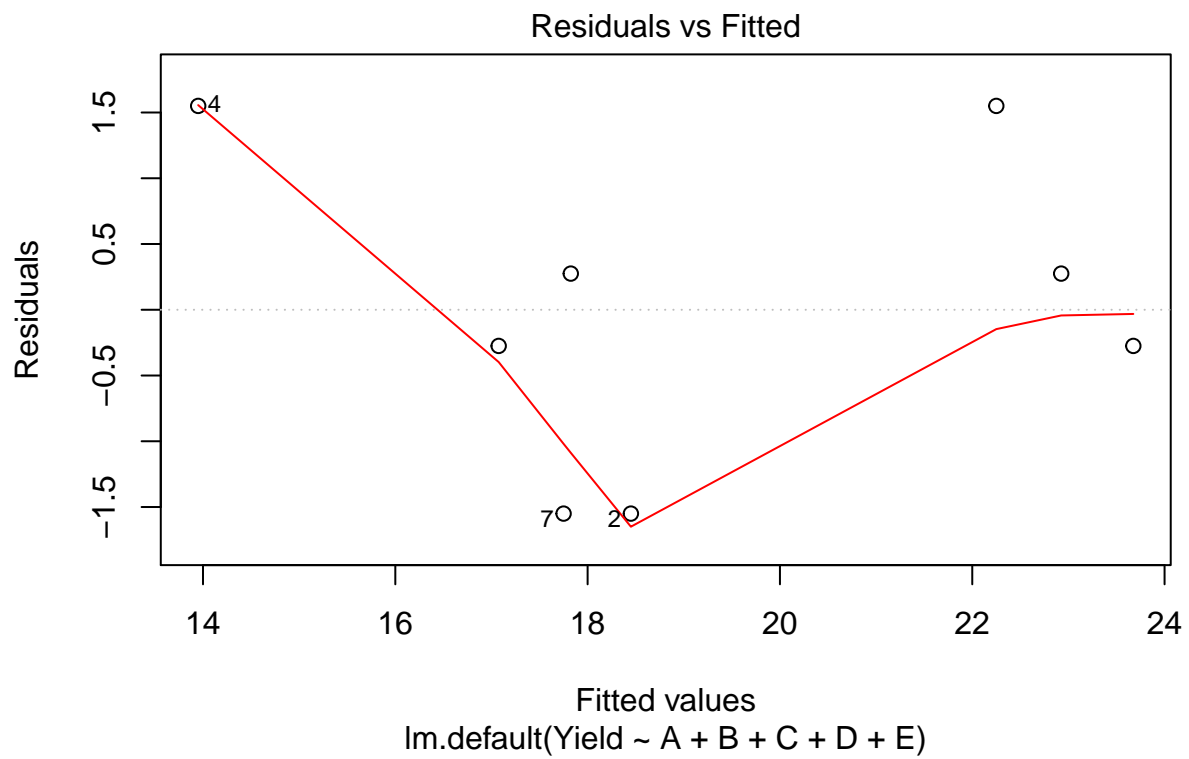
```
anova(lm(Yield ~ (A + B + C + D + E), df))
```

```
## Analysis of Variance Table
##
## Response: Yield
##      Df Sum Sq Mean Sq F value Pr(>F)
## A      1  4.651    4.651    0.9385 0.4349
## B      1 53.561   53.561   10.8068 0.0814 .
## C      1 10.351   10.351    2.0885 0.2853
## D      1  0.911    0.911    0.1839 0.7098
## E      1 10.351   10.351    2.0885 0.2853
## Residuals 2  9.913    4.956
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

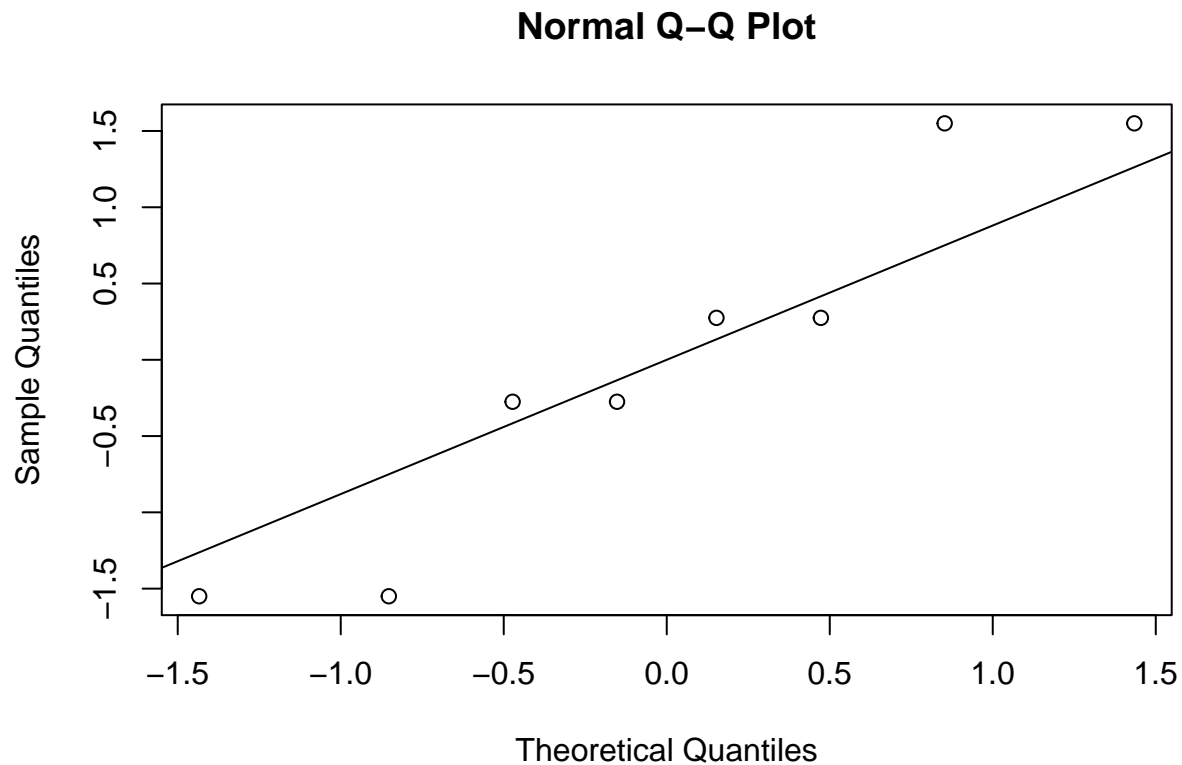
e

The residual plot is satisfactory. The Normal QQ plot of residuals shows that they are approximately normal.

```
plot(m, 1)
```



```
qqnorm(m$residuals)  
qqline(m$residuals)
```



## 8.23

```
df <- read_excel("~/vmshare/stats 101b datasets/CH 8 (P 23).xlsx")
colnames(df)[1:5] <- c(LETTERS[1:5])
```

a

Given generators  $I = ABD$  and  $I = BCE$  then the product of the columns must be the identity. In addition the complete defining relation is  $I = ABD = BCE = ACDE$

```
df$A*df$B*df$D
```

```
## [1] 1 1 1 1 1 1 1 1
```

```
df$B*df$C*df$E
```

```
## [1] 1 1 1 1 1 1 1 1
```

Effect Estimates up to second order

```
m <- lm(`Avg Annual Cost` ~ (A+B+C+D+E)^2, df)
summary(m)
```

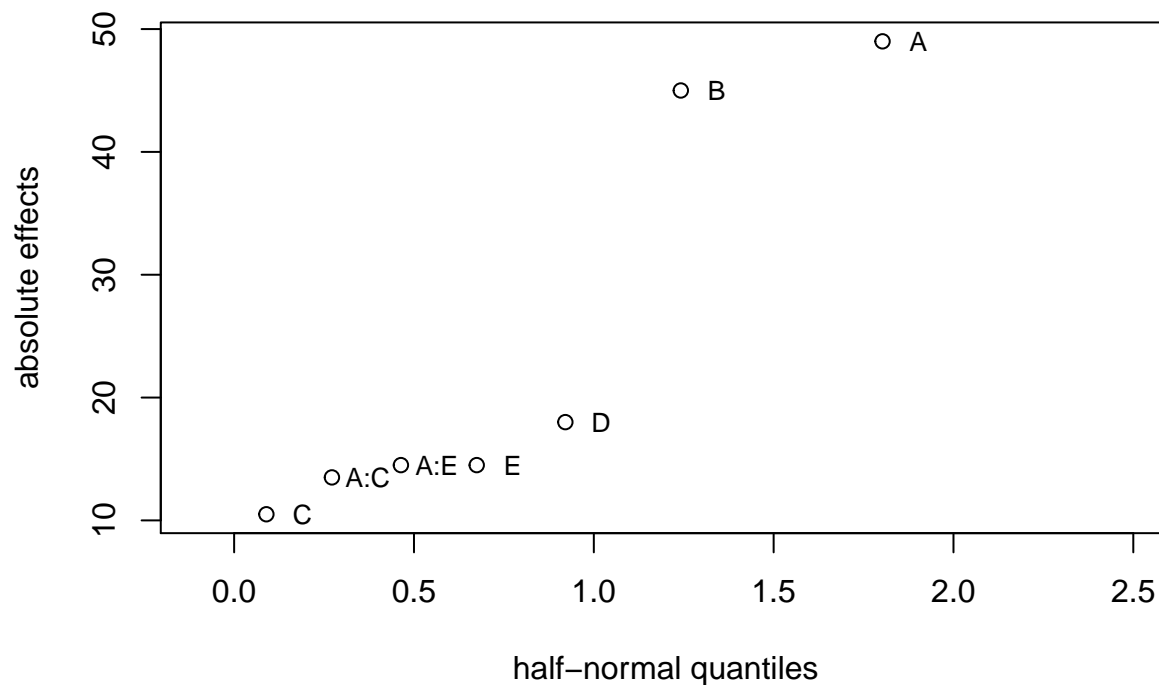
```
##
## Call:
## lm.default(formula = `Avg Annual Cost` ~ (A + B + C + D + E)^2,
##           data = df)
##
## Residuals:
## ALL 8 residuals are 0: no residual degrees of freedom!
##
## Coefficients: (8 not defined because of singularities)
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)   149.50         NA      NA      NA
## A              24.50         NA      NA      NA
## B              22.50         NA      NA      NA
## C               5.25         NA      NA      NA
## D             -9.00         NA      NA      NA
## E             -7.25         NA      NA      NA
## A:B              NA         NA      NA      NA
## A:C              6.75         NA      NA      NA
## A:D              NA         NA      NA      NA
## A:E             -7.25         NA      NA      NA
## B:C              NA         NA      NA      NA
## B:D              NA         NA      NA      NA
## B:E              NA         NA      NA      NA
## C:D              NA         NA      NA      NA
## C:E              NA         NA      NA      NA
## D:E              NA         NA      NA      NA
##
## Residual standard error: NaN on 0 degrees of freedom
## Multiple R-squared:      1, Adjusted R-squared:      NaN
## F-statistic:      NaN on 7 and 0 DF, p-value: NA
```

```
effects <- coef(m)[!is.na(coef(m))]
effects <- 2*effects[-1]; effects
```

```
##      A      B      C      D      E      A:C      A:E
## 49.0 45.0 10.5 -18.0 -14.5 13.5 -14.5
```

```
halfnormalplot(effects, label = T)
```

## Half-Normal Plot



Effects A and B seem to be significant.

b

This design was created by reversing the signs of column A.

```
df <- read_excel("~/vmshare/stats 101b datasets/CH8 (P.23b).xlsx")
colnames(df)[1:6] <- c("Block Order", LETTERS[1:5])
```

```
m <- lm(`Avg Annual Cost` ~ (A+B+C+D+E)^3, df)
summary(m)
```

```
##
## Call:
## lm.default(formula = `Avg Annual Cost` ~ (A + B + C + D + E)^3,
##   data = df)
##
## Residuals:
## ALL 16 residuals are 0: no residual degrees of freedom!
##
## Coefficients: (10 not defined because of singularities)
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   146.500         NA      NA      NA
## A              22.125         NA      NA      NA
## B              24.625         NA      NA      NA
## C               3.250         NA      NA      NA
## D             -4.000         NA      NA      NA
## E             -4.125         NA      NA      NA
```

```
## A:B          -5.000      NA      NA      NA
## A:C           3.625      NA      NA      NA
## A:D          -2.125      NA      NA      NA
## A:E          -3.000      NA      NA      NA
## B:C           NA       NA      NA      NA
## B:D           2.375      NA      NA      NA
## B:E           NA       NA      NA      NA
## C:D          -4.250      NA      NA      NA
## C:E           NA       NA      NA      NA
## D:E           3.125      NA      NA      NA
## A:B:C         NA       NA      NA      NA
## A:B:D         3.000      NA      NA      NA
## A:B:E         NA       NA      NA      NA
## A:C:D        -3.125      NA      NA      NA
## A:C:E         NA       NA      NA      NA
## A:D:E         2.000      NA      NA      NA
## B:C:D         NA       NA      NA      NA
## B:C:E         NA       NA      NA      NA
## B:D:E         NA       NA      NA      NA
## C:D:E         NA       NA      NA      NA
##
## Residual standard error: NaN on 0 degrees of freedom
## Multiple R-squared:      1, Adjusted R-squared:      NaN
## F-statistic:      NaN on 15 and 0 DF, p-value: NA
```

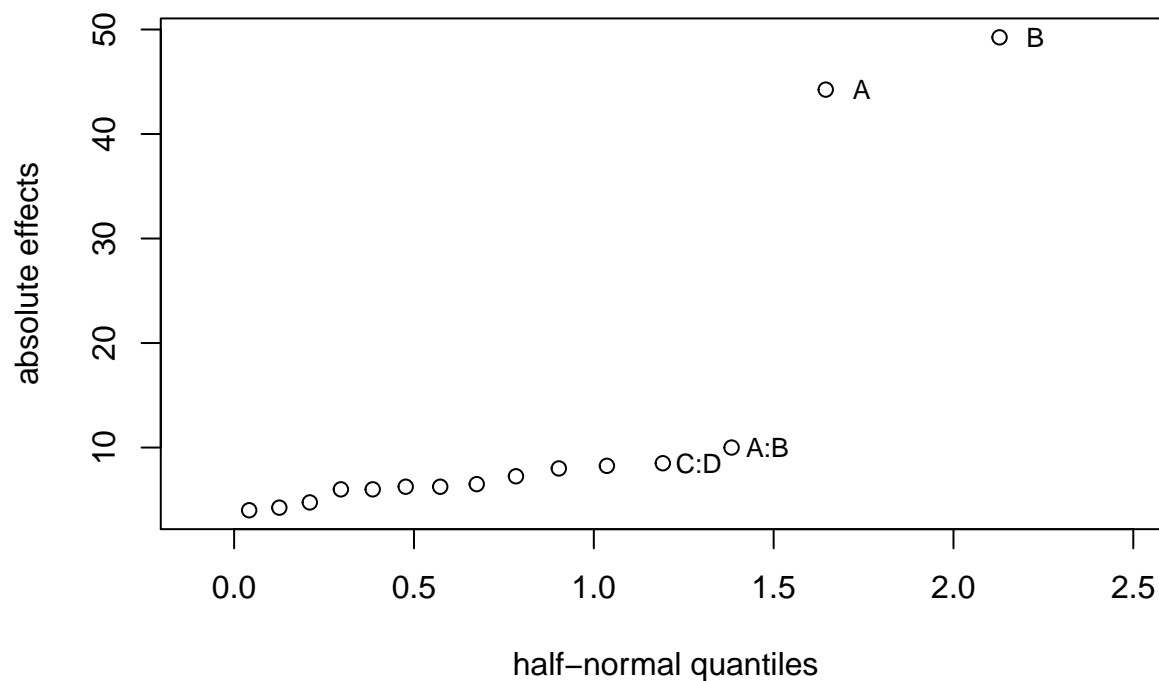
```
effects <- coef(m)[!is.na(coef(m))]
effects <- 2*effects[-1]; effects
```

```
##      A      B      C      D      E      A:B      A:C      A:D      A:E      B:D
## 44.25 49.25  6.50 -8.00 -8.25 -10.00   7.25 -4.25 -6.00  4.75
##      C:D      D:E      A:B:D      A:C:D      A:D:E
## -8.50   6.25   6.00 -6.25   4.00
```

```
halfnormalplot(effects, label = T, n=4)
```



## Half-Normal Plot



A and B are still significant according to the half-normal probability plot.

c

This design was obtained by reversing the sign of all columns.

```
df <- read_excel("~/vmshare/Stats 101B Datasets/CH 8 (P.23c).xlsx")
colnames(df)[1:6] <- c("Block Order", LETTERS[1:5])
```

```
m <- lm(`Avg Annual Cost` ~ (A+B+C+D+E)^3, df)
summary(m)
```

```
##
## Call:
## lm.default(formula = `Avg Annual Cost` ~ (A + B + C + D + E)^3,
##           data = df)
##
## Residuals:
## ALL 16 residuals are 0: no residual degrees of freedom!
##
## Coefficients: (10 not defined because of singularities)
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   146.875         NA      NA      NA
## A              21.875         NA      NA      NA
## B              25.125         NA      NA      NA
## C               2.250         NA      NA      NA
## D             -4.375         NA      NA      NA
## E             -3.750         NA      NA      NA
```

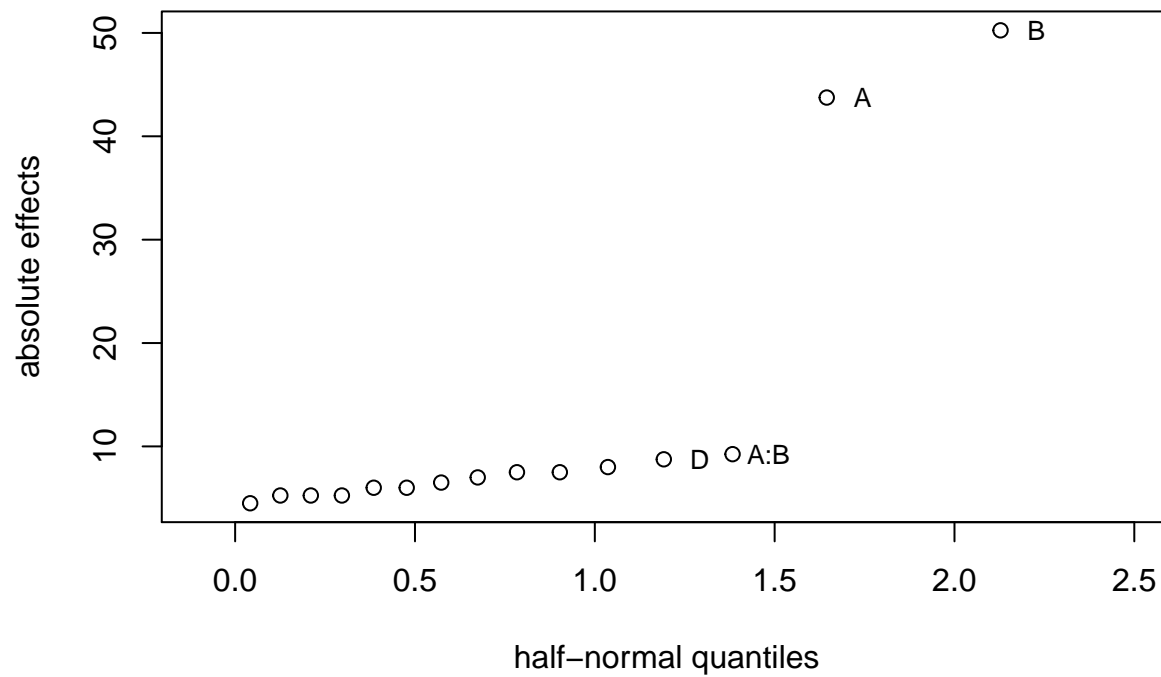
```
## A:B          -4.625      NA      NA      NA
## A:C          3.000      NA      NA      NA
## A:D         -2.625      NA      NA      NA
## A:E         -3.250      NA      NA      NA
## B:C         -3.500      NA      NA      NA
## B:D          2.625      NA      NA      NA
## B:E          3.000      NA      NA      NA
## C:D           NA      NA      NA      NA
## C:E           NA      NA      NA      NA
## D:E           NA      NA      NA      NA
## A:B:C        -4.000      NA      NA      NA
## A:B:D         2.625      NA      NA      NA
## A:B:E         3.750      NA      NA      NA
## A:C:D         NA      NA      NA      NA
## A:C:E         NA      NA      NA      NA
## A:D:E         NA      NA      NA      NA
## B:C:D         NA      NA      NA      NA
## B:C:E         NA      NA      NA      NA
## B:D:E         NA      NA      NA      NA
## C:D:E         NA      NA      NA      NA
##
## Residual standard error: NaN on 0 degrees of freedom
## Multiple R-squared:      1, Adjusted R-squared:      NaN
## F-statistic:      NaN on 15 and 0 DF, p-value: NA
```

```
effects <- coef(m)[!is.na(coef(m))]
effects <- 2*effects[-1]; effects
```

```
##      A      B      C      D      E  A:B  A:C  A:D  A:E  B:C  B:D  B:E
## 43.75 50.25  4.50 -8.75 -7.50 -9.25  6.00 -5.25 -6.50 -7.00  5.25  6.00
## A:B:C A:B:D A:B:E
## -8.00  5.25  7.50
```

```
halfnormalplot(effects, label = T, n=4)
```

## Half-Normal Plot



A and B continue to be significant effects.

## 8.37

```
#df <- read_excel("~/Stats 101B Datasets/CH 8 (p.37).xlsx")
df <- read_excel("~/vmshare/stats 101b datasets/CH 8 (p.37).xlsx")
colnames(df)[1:8] <- c(LETTERS[1:8])
dx <- scale(df[1:8], scale = F)
dx <- sign(dx)
df[,1:8] <- dx
```

a

Given  $I = ABCF$ ,  $I = ABDG$ , and  $I = BCDEH$  for this design. We multiply the respective columns and expect for them to equal the identity.

```
df$A*df$B*df$C*df$F
```

```
## [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
df$A*df$B*df$D*df$G
```

```
## [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
df$B*df$C*df$D*df$E*df$H
```

```
## [1] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

b

```
m <- lm(PVM ~ (A+B+C+D+E+F+G+H)^3,df)
alias(m)
```

```
## Model :
## PVM ~ (A + B + C + D + E + F + G + H)^3
##
## Complete :
##      (Intercept) A B C D E F G H A:B A:C A:D A:E A:F A:G A:H B:E B:H C:D
## A:C:E 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:C:F 0          0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:C:G 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:C:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:D:E 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:D:F 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:D:G 0          0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:D:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:E:F 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:E:G 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:E:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:F:G 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:F:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## A:G:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:C:D 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:C:E 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:C:F 0          1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:C:G 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:C:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:D:E 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:D:F 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:D:G 0          1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:D:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:E:F 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:E:G 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:E:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
## B:F:G 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:F:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## B:G:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## C:D:E 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
## C:D:F 0          0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
## C:D:G 0          0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
## C:D:H 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
## C:E:F 0          0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## C:E:G 0          0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0
## C:E:H 0          0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0
## C:F:G 0          0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

## C:F:H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
## C:G:H	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
## D:E:F	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
## D:E:G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
## D:E:H	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
## D:F:G	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
## D:F:H	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
## D:G:H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
## E:F:G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
## E:F:H	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
## E:G:H	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
## F:G:H	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
## B:C	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
## B:D	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
## B:F	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
## B:G	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
## C:F	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
## D:F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
## D:G	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
## F:G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
## A:B:C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
## A:B:D	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
## A:B:F	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
## A:B:G	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
##	C:E	C:G	C:H	D:E	D:H	E:F	E:G	E:H	F:H	G:H	A:B:E	A:B:H	A:C:D				
## A:C:E	0	0	0	0	0	0	0	0	0	1	0	0	0				
## A:C:F	0	0	0	0	0	0	0	0	0	0	0	0	0				
## A:C:G	0	0	0	0	0	0	0	1	0	0	0	0	0				
## A:C:H	0	0	0	0	0	0	1	0	0	0	0	0	0				
## A:D:E	0	0	0	0	0	0	0	0	1	0	0	0	0				
## A:D:F	0	0	0	0	0	0	0	1	0	0	0	0	0				
## A:D:G	0	0	0	0	0	0	0	0	0	0	0	0	0				
## A:D:H	0	0	0	0	1	0	0	0	0	0	0	0	0				
## A:E:F	0	0	0	1	0	0	0	0	0	0	0	0	0				
## A:E:G	0	1	0	0	0	0	0	0	0	0	0	0	0				
## A:E:H	1	0	0	0	0	0	0	0	0	0	0	0	0				
## A:F:G	0	0	0	0	0	0	0	0	0	0	0	0	1				
## A:F:H	0	0	1	0	0	0	0	0	0	0	0	0	0				
## A:G:H	1	0	0	0	0	0	0	0	0	0	0	0	0				
## B:C:D	0	0	0	0	0	0	0	1	0	0	0	0	0				
## B:C:E	0	0	0	1	0	0	0	0	0	0	0	0	0				
## B:C:F	0	0	0	0	0	0	0	0	0	0	0	0	0				
## B:C:G	0	0	0	0	0	0	0	0	0	0	0	0	1				
## B:C:H	0	0	1	0	0	0	0	0	0	0	0	0	0				
## B:D:E	0	1	0	0	0	0	0	0	0	0	0	0	0				
## B:D:F	0	0	0	0	0	0	0	0	0	0	0	0	1				
## B:D:G	0	0	0	0	0	0	0	0	0	0	0	0	0				
## B:D:H	1	0	0	0	0	0	0	0	0	0	0	0	0				
## B:E:F	0	0	0	0	0	0	0	0	1	0	0	0	0				
## B:E:G	0	0	0	0	0	0	0	1	0	0	0	0	0				
## B:E:H	0	0	0	0	0	0	0	0	0	0	0	0	0				
## B:F:G	0	0	0	0	0	0	1	0	0	0	0	0	0				
## B:F:H	0	0	0	0	0	1	0	0	0	0	0	0	0				
## B:G:H	0	0	0	0	1	0	0	0	0	0	0	0	0				

## C:D:E	0	0	0	0	0	0	0	0	0	0	0	0
## C:D:F	0	0	0	0	0	0	0	0	0	0	0	0
## C:D:G	0	0	0	0	0	0	0	0	0	0	0	0
## C:D:H	0	0	0	0	0	0	0	0	0	0	0	0
## C:E:F	0	0	0	0	0	0	0	0	0	1	0	0
## C:E:G	0	0	0	0	0	0	0	0	0	0	0	0
## C:E:H	0	0	0	0	0	0	0	0	0	0	0	0
## C:F:G	0	0	0	0	0	0	0	0	0	0	0	0
## C:F:H	0	0	0	0	0	0	0	0	0	0	1	0
## C:G:H	0	0	0	0	0	0	0	0	0	0	0	0
## D:E:F	0	0	0	0	0	0	0	0	0	0	0	0
## D:E:G	0	0	0	0	0	0	0	0	0	1	0	0
## D:E:H	0	0	0	0	0	0	0	0	0	0	0	0
## D:F:G	0	0	0	0	0	0	0	0	0	0	0	0
## D:F:H	0	0	0	0	0	0	0	0	0	0	0	0
## D:G:H	0	0	0	0	0	0	0	0	0	0	1	0
## E:F:G	0	0	0	0	0	0	0	0	0	0	0	0
## E:F:H	0	0	0	0	0	0	0	0	0	0	0	0
## E:G:H	0	0	0	0	0	0	0	0	0	0	0	0
## F:G:H	0	0	0	0	0	0	0	0	0	0	0	0
## B:C	0	0	0	0	0	0	0	0	0	0	0	0
## B:D	0	0	0	0	0	0	0	0	0	0	0	0
## B:F	0	0	0	0	0	0	0	0	0	0	0	0
## B:G	0	0	0	0	0	0	0	0	0	0	0	0
## C:F	0	0	0	0	0	0	0	0	0	0	0	0
## D:F	0	1	0	0	0	0	0	0	0	0	0	0
## D:G	0	0	0	0	0	0	0	0	0	0	0	0
## F:G	0	0	0	0	0	0	0	0	0	0	0	0
## A:B:C	0	0	0	0	0	0	0	0	0	0	0	0
## A:B:D	0	0	0	0	0	0	0	0	0	0	0	0
## A:B:F	0	0	0	0	0	0	0	0	0	0	0	0
## A:B:G	0	0	0	0	0	0	0	0	0	0	0	0

<i>Effect</i>	<i>Aliases</i>
<i>A</i>	<i>A</i>
<i>B</i>	<i>B</i>
<i>C</i>	<i>C</i>
<i>D</i>	<i>D</i>
<i>E</i>	<i>E</i>
<i>F</i>	<i>F</i>
<i>G</i>	<i>G</i>
<i>H</i>	<i>H</i>
<i>AB</i>	<i>AB + CF + DG</i>
<i>AC</i>	<i>AC + BF</i>
<i>AD</i>	<i>AD + BG</i>
<i>AE</i>	<i>AE</i>
<i>AF</i>	<i>AF + BC</i>
<i>AG</i>	<i>AG + BD</i>
<i>AH</i>	<i>AH</i>
<i>BE</i>	<i>BE</i>
<i>BH</i>	<i>BH</i>
<i>CD</i>	<i>CD + FG</i>
<i>CE</i>	<i>CE</i>
<i>CG</i>	<i>CG + DF</i>
<i>CH</i>	<i>CH</i>
<i>DE</i>	<i>DE</i>
<i>DH</i>	<i>DH</i>
<i>EF</i>	<i>EF</i>
<i>EG</i>	<i>EG</i>
<i>EH</i>	<i>EH</i>
<i>FH</i>	<i>FH</i>
<i>GH</i>	<i>GH</i>

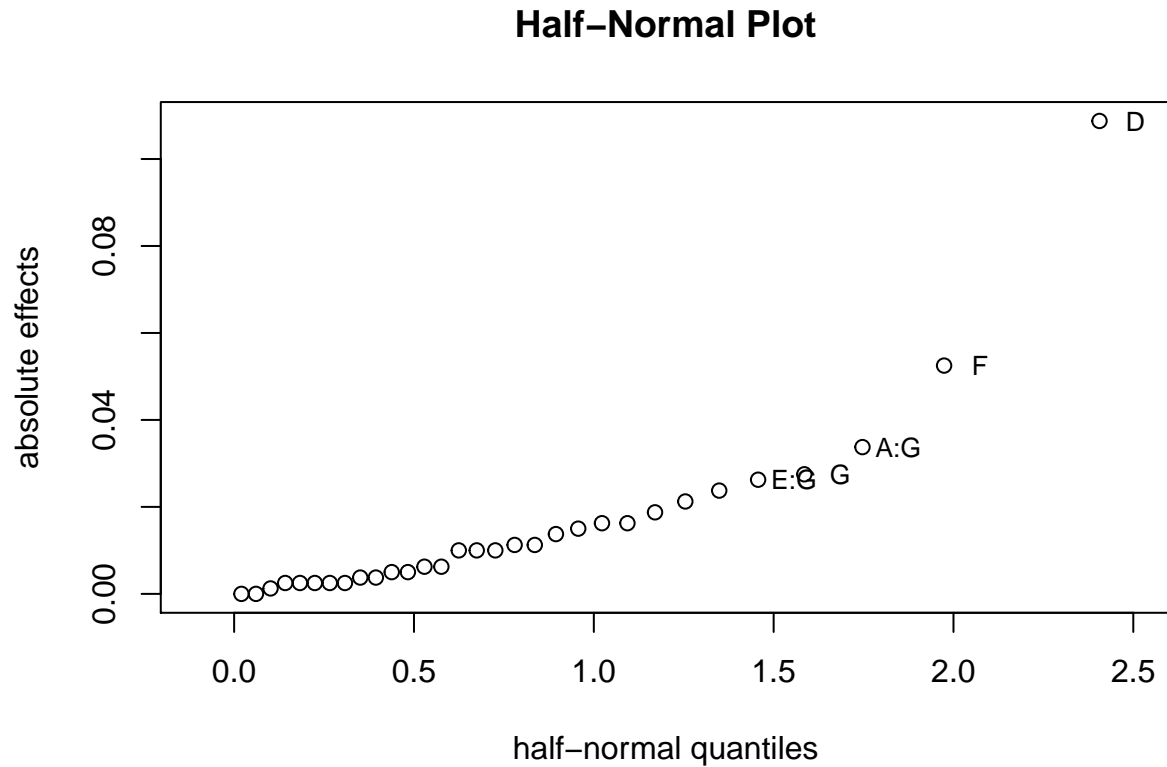
**c**

**PVM response:** D and F are significant responses according to the half-normal probability plot.

```
m_pvn <- lm(PVM ~ (A+B+C+D+E+F+G+H)^3,df)
effects <- coef(m_pvn)[!is.na(coef(m_pvn))]
effects <- 2*effects[-1];effects
```

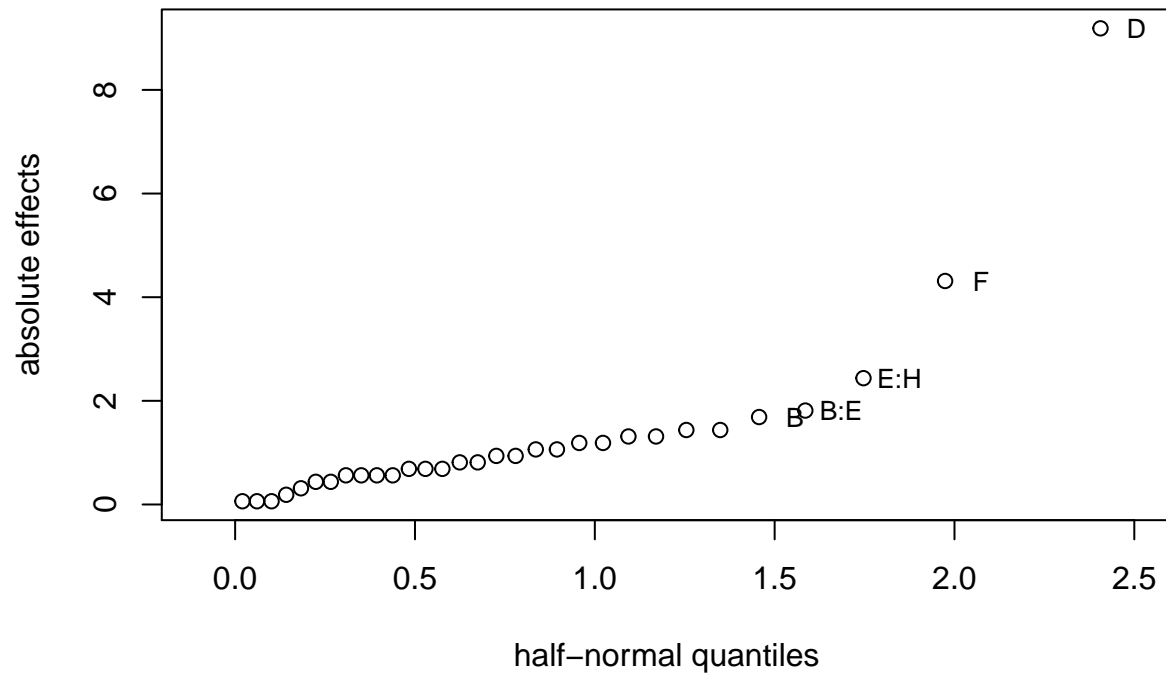
```
##           A           B           C           D           E
## -3.750000e-03  2.500000e-03 -1.125000e-02  1.087500e-01  1.875000e-02
##           F           G           H           A:B           A:C
##  5.250000e-02  2.750000e-02  1.625000e-02 -1.375000e-02  2.500000e-03
##           A:D           A:E           A:F           A:G           A:H
## -2.500000e-03 -1.000000e-02 -1.625000e-02  3.375000e-02 -2.500000e-03
##           B:E           B:H           C:D           C:E           C:G
## -1.125000e-02  2.125000e-02  5.000000e-03 -2.157528e-16  2.375000e-02
##           C:H           D:E           D:H           E:F           E:G
##  1.500000e-02  1.000000e-02  2.185740e-16  1.250000e-03  2.625000e-02
##           E:H           F:H           G:H           A:B:E           A:B:H
## -1.000000e-02 -3.750000e-03  6.250000e-03 -5.000000e-03 -2.500000e-03
##           A:C:D
## -6.250000e-03
```

```
halfnormalplot(effects, label=T, n=5)
```





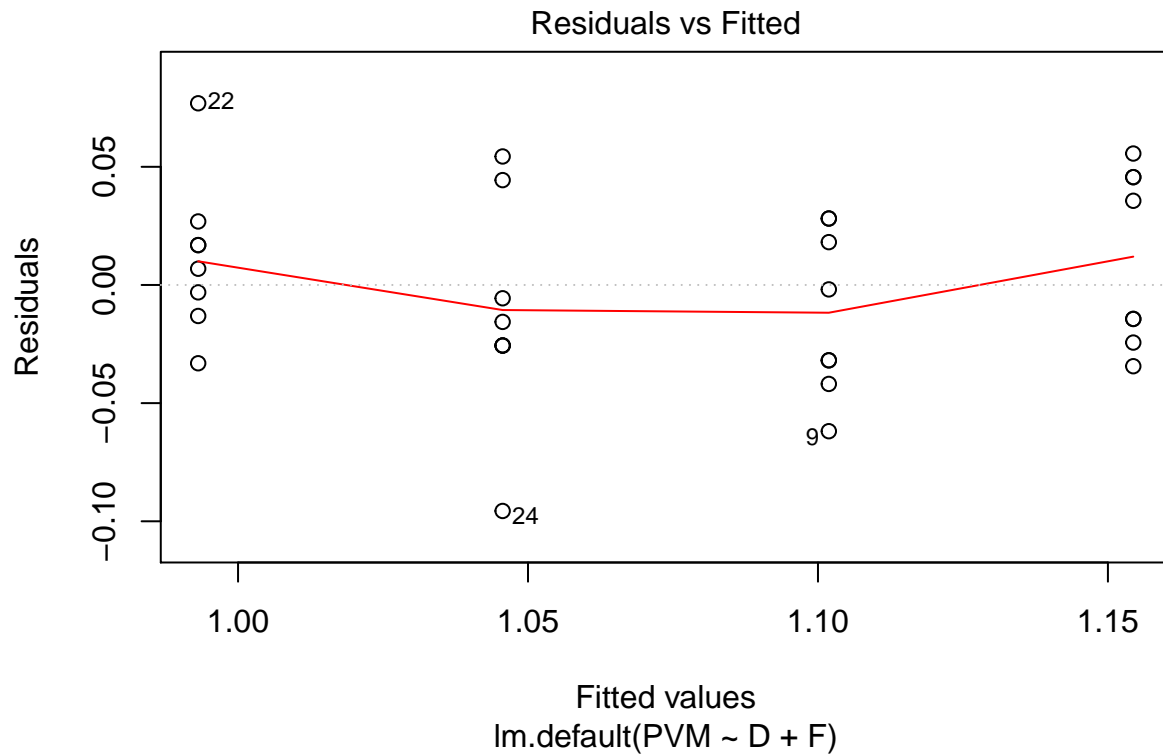
## Half-Normal Plot



d

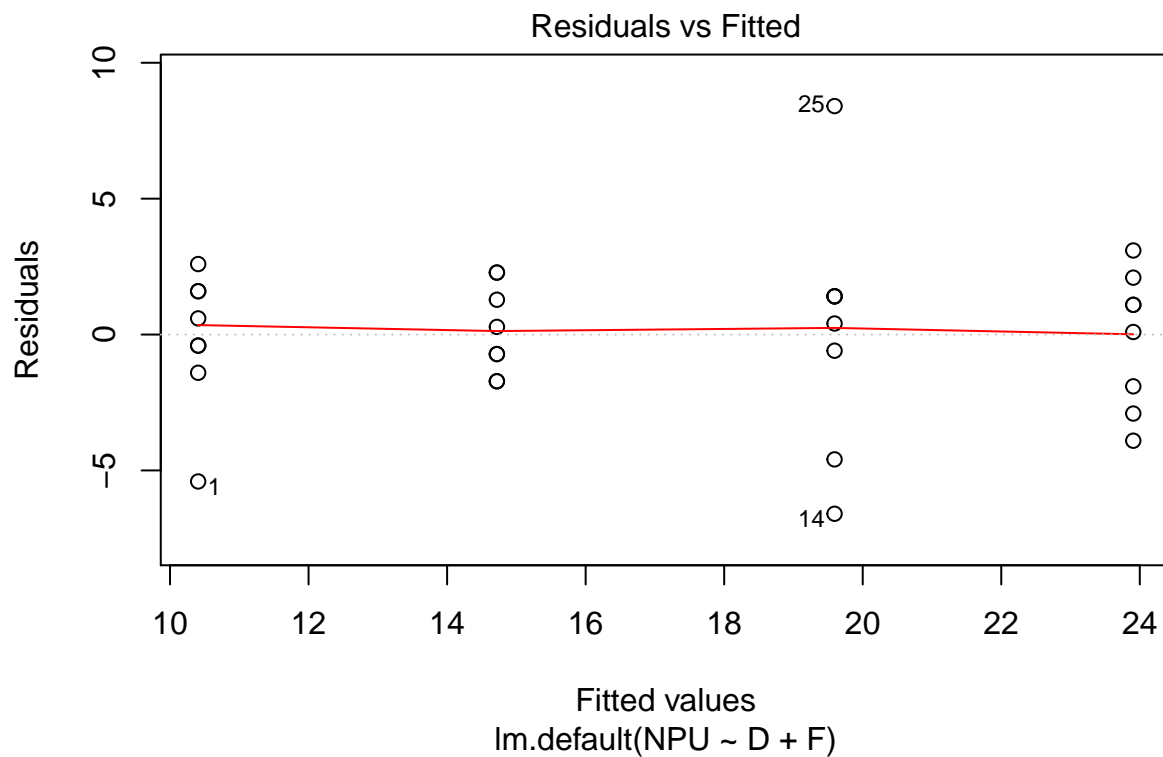
**Residuals for PVN:** There is nothing evidently wrong with the residuals, there is one point that may be a outlier and its point 25.

```
m_pvn <- lm(PVM ~ D+F, df)
plot(m_pvn, 1)
```



**Residuals for NPU:** There is also nothing evidently wrong with the residuals in this model. We do have a outlier which is again point 25.

```
m_npu <- lm(NPU ~ D+F, df)
plot(m_npu, 1)
```



e

The model suggest setting the temperature to 20° and a cleaning interval of 8 strokes.

```
summary(m_npu)
```

```
##
## Call:
## lm.default(formula = NPU ~ D + F, data = df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -6.5938 -1.4844  0.3438  1.4531  8.4062
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  17.1562     0.5171   33.177 < 2e-16 ***
## D              4.5938     0.5171    8.883 9.02e-10 ***
## F              2.1563     0.5171    4.170 0.000252 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.925 on 29 degrees of freedom
## Multiple R-squared:  0.7686, Adjusted R-squared:  0.7526
## F-statistic: 48.15 on 2 and 29 DF,  p-value: 6.087e-10
```

## 8.39

- a 5 factors
- b 3 Basic design factors
- c  $I = ABD$  and  $I = -ACE$
- d No
- e  $I = ABD = -ACE = -BCDE$
- f Resolution 3

## 8.48

- a  $D = -ABC$
- b  $E = BC$
- c Resolution 3