4. *Use the sample means and an estimate of σ based on the oneway ANOVA to estimate the sample size needed for a CRD to achieve:*

```r
# create dataset with means
nitrogen <- c(rep(1,4), rep(2,4), rep(3,4), rep(4,4), rep(5,4), rep(6,4))
reps <- c(rep(c(1,2,3,4), 6))
yield <- c(32.1,35.6,41.9,35.4,30.1,31.5,37.1,30.8,
           25.4,27.4,33.8,31.1,24.1,33.0,35.6,31.4,
           26.1,31,33.8,31.9,23.2,24.8,26.7,26.7)

p4 <- data.frame(cbind(nitrogen, reps, yield))
p4$nitrogen <- as.factor(as.character(p4$nitrogen))

p4means <- aggregate(p4$yield, list(p4$nitrogen), mean)
colnames(p4means) <- c("Nitrogen", "Mean")

#write.csv(p4means, file = "p4means.csv")
#check
t1 <- c(32.1,35.6,41.9,35.4)
t2 <- c(30.1,31.5,37.1,30.8)
t3 <- c(25.4,27.4,33.8,31.1)
t4 <- c(24.1,33,35.6,31.4)
t5 <- c(26.1,31,33.8,31.9)
t6 <- c(23.2,24.8,26.7,26.7)

apply(data.frame(cbind(t1,t2,t3,t4,t5,t6)), 2, mean)
```

```
PROC GLMPOWER DATA = p4means;
CLASS nitrogen;
MODEL mean=nitrogen;
POWER
STDDEV = 3.671833
ALPHA = 0.05 0.01
NTOTAL = .
POWER = 0.78 0.79 0.8 0.82 0.86 0.87 0.88 0.89 0.9 0.905 0.91 0.92 0.92 0.93 0.94 0.95;
RUN;
```

Computed N Total					
Index	Alpha	Nominal Power	Error DF	Actual Power	N Total
1	0.05	0.780	18	0.840	24
2	0.05	0.790	18	0.840	24
3	0.05	0.800	18	0.840	24
4	0.05	0.820	18	0.840	24
5	0.05	0.860	24	0.939	30
6	0.05	0.870	24	0.939	30
7	0.05	0.880	24	0.939	30
8	0.05	0.890	24	0.939	30
9	0.05	0.900	24	0.939	30
10	0.05	0.905	24	0.939	30
11	0.05	0.910	24	0.939	30
12	0.05	0.920	24	0.939	30
13	0.05	0.920	24	0.939	30
14	0.05	0.930	24	0.939	30
15	0.05	0.940	30	0.979	36
16	0.05	0.950	30	0.979	36
17	0.01	0.780	24	0.783	30
18	0.01	0.790	30	0.901	36
19	0.01	0.800	30	0.901	36
20	0.01	0.820	30	0.901	36
21	0.01	0.860	30	0.901	36
22	0.01	0.870	30	0.901	36
23	0.01	0.880	30	0.901	36
24	0.01	0.890	30	0.901	36
25	0.01	0.900	30	0.901	36
26	0.01	0.905	36	0.959	42
27	0.01	0.910	36	0.959	42
28	0.01	0.920	36	0.959	42
29	0.01	0.920	36	0.959	42
30	0.01	0.930	36	0.959	42
31	0.01	0.940	36	0.959	42
32	0.01	0.950	36	0.959	42

(a) *A power of at least 0.95 for the ANOVA F-test assuming $\alpha = 0.05$.*

Using a total sample size of 36 (6 per group), the observed power is 0.979.

(b) *A power of at least 0.90 for the ANOVA F-test assuming $\alpha = 0.01$.*

Using a total sample size of 36 (6 per group), with these parameters set we get a power of 0.901.

(c) *What would the estimated power for the ANOVA F-test assuming n=2 replicates are to be taken for each treatment and assuming $\alpha = 0.05$?*

The computed power is 0.317.

Fixed Scenario Elements	
Dependent Variable	Mean
Source	Nitrogen
Alpha	0.05
Error Standard Deviation	3.671833
Total Sample Size	12
Test Degrees of Freedom	5
Error Degrees of Freedom	6

Computed Power
Power
0.317

	VAR1	Nitrogen	Mean
1	1	1	36.25
2	2	2	32.375
3	3	3	29.425
4	4	4	31.025
5	5	5	30.7
6	6	6	25.35

5. *(5pt) Stat 541 Students: Read Section 4.3 (pages 165-168) on Graeco-Latin squares. Consider the following experiment. A food processor wants to determine the effect of package design on the sale of one of her company's products. She had five designs to be tested: A, B, C, D, E. There were several sources of variation, however, whose possible effects were to be accounted for in the study. These included (1) day of the week, (2) differences among stores, and (3) effect of shelf height. She decided to use a Graeco-Latin square with five weekdays (M, Tu, W, Th, F,) for the row blocks, five stores for the column blocks, and five shelf heights for the Greek letter blocks. The experimental design and sales in dollars are shown in the following table.*

In the original dataset, I had missed one column of the *latin* letters, making an incorrect dataset.

```
# create latin squares data set

rowsday <- c(rep(c("Mon", "Tues", "Wed", "Thurs", "Fri"),5))
```

```r
colstore <- c(rep("I", 5), rep("II", 5), rep("III", 5),
              rep("IV", 5), rep("V", 5))
latin <- c("E", "D", "B", "C", "A", "C", "B", "E", "A", "D",
           "B", "A", "D", "E", "C","D", "C", "A", "B", "E", "A", "E", "C", "D", "B")

greek <- c("alpha", "delta", "epsilon", "beta", "gamma", "delta",
           "beta", "gamma", "epsilon", "alpha", "gamma", "alpha",
           "beta", "delta", "epsilon", "epsilon", "gamma", "delta",
           "alpha", "beta", "beta", "epsilon", "alpha", "gamma", "delta")

dollars <- c(238,149,222,187,65,228,220,295,66,118,158,92,104,242,
             279,188,169,54,122,278,74,282,213,90,176)

p5data <- data.frame(cbind(rowsday, colstore, latin, greek, dollars))

dim(p5data)

[1] 25  5

aggregate(as.numeric(as.character(p5data$dollars)), list(as.factor(p5data$rowsday)), mean)

  Group.1     x
1     Fri 183.2
2     Mon 177.2
3   Thurs 141.4
4    Tues 182.4
5     Wed 177.6

#write.csv(p5data, file = "p5data.csv")

mon <- c(238,228,158,188,74)
tues <- c(149,220,92,169,282)
wed <- c(222,295,104,54,213)
thurs <- c(187,66,242,122,90)
fri <- c(65,118,279,278,176)
c(mean(mon), mean(tues), mean(wed), mean(thurs), mean(fri))

[1] 177.2 182.4 177.6 141.4 183.2
```

(a) *Perform an ANOVA. State the null and alternative hypotheses of interest, and your conclusions. You can use α = .05 for testing.*

$Y_{ijkl} = \mu + \beta_i + \gamma_j + \psi_k + \tau_l + \epsilon_{ijkl}$

Let τ_l represents the effect of design l which is an element of the set A,B,C,D,E.

H_o: $\tau_A = \tau_B = \tau_C = \tau_D = \tau_E$

H_a: at least one $\tau_l \neq \tau_{l'}$ for $l \neq l'$

There is strong evidence of a design effect on the true mean price (P<0.0001). At the $\alpha = 0.05$ cutoff, the design did have an effect on the true mean price after accounting for the store, shelf, and weekday effects.

```
proc glm data=p5data1;
title 'Graeco-Latin Square';
class rowsday colstore latin greek;
model newdollar = rowsday colstore latin greek;
means latin / tukey alpha=0.05;
run;
```

Source	DF	Type III SS	Mean Square	F Value	Pr > F
rowsday	4	6138.5600	1534.6400	1.66	0.2510
colstore	4	1544.9600	386.2400	0.42	0.7919
latin	4	115462.1600	28865.5400	31.21	<.0001
greek	4	8852.1600	2213.0400	2.39	0.1366

(b) *Include a Tukey multiple comparison procedure, and your conclusions from it.*

The empirical mean cost increased in the order of A, D, B, C, and the highest mean cost was with design E. Using the 95% Tukey adjusted family-wise confidence level, there is no evidence the mean cost differed for designs A and D, but strong evidence mean cost for design A differed from mean cost for designs B, C, and E. There is no evidence the mean cost differed for designs D and B, but strong evidence mean cost for design D differed from mean cost from designs C and E. There is no evidence mean cost for design B differed from that of design C, but strong evidence mean cost for design B differed from mean cost of design E. There is no evidence mean cost of design C differed from mean cost of design E.

Means with the same letter are not significantly different.				
Tukey Grouping		Mean	N	latin
	A	267.00	5	E
	A			
B	A	215.20	5	C
B				
B	C	179.60	5	B
	C			
D	C	129.80	5	D
D				
D		70.20	5	A