Yale Quan
006693828
STAT 530

3.10

Cotton %	Obs Strength					$Y_{i\cdot}$	$\bar{Y}_{i\cdot}$
15	7	7	15	11	9	49	9.8
20	12	17	12	18	18	77	15.4
25	14	19	19	18	18	88	17.6
30	19	25	22	19	23	108	21.6
35	7	10	11	15	11	54	10.8

$Y_{\cdot\cdot} = 376$

$\bar{Y}_{\cdot\cdot} = 15.04$

$N = 25 \quad n = 5 \quad a = 5$

$$SSTO = \sum\sum Y_{ij}^2 - \frac{Y_{\cdot\cdot}^2}{N} = 7^2 + 7^2 + \dots + 11^2 - \frac{376^2}{25} = 6292 - 5655.04 = 636.96$$

$$SSTR = \frac{1}{n}\sum Y_{i\cdot}^2 - \frac{Y_{\cdot\cdot}^2}{N} = \frac{1}{5}\left(49^2 + 77^2 + \dots + 54^2\right) - \frac{376^2}{25} = 6130.8 - 5644.04 = 475.76$$

$$SSE = SSTO - SSTR = 636.96 - 475.76 = 161.20$$

Source	df	SS	MSE	F	P-value
Treatment	4	475.76	118.94	14.76	9.1279×10^{-6}
Error	20	161.20	8.06		
Total	24	636.90			

Since P-value $= 9.1279 \times 10^{-6} < \alpha = .05$ we reject the null that all means are equal and conclude that cotton content affects the mean tensile strength

b) $LSD = t_{\frac{\alpha}{2}}(N-a)\sqrt{\frac{2MSE}{n}}$ Tukey $T = q_\alpha(a,f)\sqrt{\frac{MSE}{n}}$

$= t_{.025}(20)\sqrt{\frac{2(8.06)}{5}}$ $= q_{.05}(5,20)\sqrt{\frac{8.06}{5}}$

$= 4.24\sqrt{1.612}$

$= 3.745$ $= 5.38$

$|\bar{Y}_{1.} - \bar{Y}_{2.}| = 5.6$

$|\bar{Y}_{1.} - \bar{Y}_{3.}| = 7.8$

$|\bar{Y}_{1.} - \bar{Y}_{4.}| = 11.8$

$|\bar{Y}_{1.} - \bar{Y}_{5.}| = 1$

$|\bar{Y}_{2.} - \bar{Y}_{3.}| = 2.2$

$|\bar{Y}_{2.} - \bar{Y}_{4.}| = 6.2$

$|\bar{Y}_{2.} - \bar{Y}_{5.}| = 4.6$

$|\bar{Y}_{3.} - \bar{Y}_{4.}| = 4$

$|\bar{Y}_{3.} - \bar{Y}_{5.}| = 6.8$

$|\bar{Y}_{4.} - \bar{Y}_{5.}| = 10.8$

For Fischer LSD $|\bar{Y}_{1.} - \bar{Y}_{5.}|$ and $|\bar{Y}_{2.} - \bar{Y}_{3.}|$ are <u>not</u> significant. Tukey T says $|\bar{Y}_{1.} - \bar{Y}_{5.}|$, $|\bar{Y}_{2.} - \bar{Y}_{3.}|$, $|\bar{Y}_{2.} - \bar{Y}_{5.}|$, $|\bar{Y}_{3.} - \bar{Y}_{4.}|$ are <u>not</u> significantly different

c) From the SAS output we can see that the Levene Test has a p-value of $.77 > .05$ so we conclude the residuals have equal variance, we can also see the plot and notice no pattern

All of the normality tests have p-value $> .05$ so we conclude the residuals are normally distributed. We can also observe the Q-Q plot and conclude normality.

2

3.10. A product developer is investigating the tensile strength of a new synthetic fiber that will be used to make cloth for men's shirts. Strength is usually affected by the percentage of cotton used in the blend of materials for the fiber. The engineer conducts a completely randomized experiment with five levels of cotton content and replicates the experiment five times. The data are shown in the following table.

Cotton Weight Percent	Observations				
15	7	7	15	11	9
20	12	17	12	18	18
25	14	19	19	18	18
30	19	25	22	19	23
35	7	10	11	15	11

(a) Is there evidence to support the claim that cotton content affects the mean tensile strength? Use $\alpha = 0.05$.

(b) Use the Fisher LSD method to make comparisons between the pairs of means. What conclusions can you draw?

(c) Analyze the residuals from this experiment and comment on model adequacy.

A) We have the following hypothesis

$$H_0: \mu_1 = \mu_2 = \cdots = \mu_5 \ vs \ H_1: at\ least\ one\ pair\ of\ \mu\ is\ not\ equal$$

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	475.7600000	118.9400000	14.76	<.0001
Error	20	161.2000000	8.0600000		
Corrected Total	24	636.9600000			

From the above SAS output we can see that the F-Statistic is 14.76 with 4 and 20 degrees of freedom. The corresponding P-value is less than 0.001. Since the p-value is less than α.= 0.05 we can conclude that the cotton content affects the mean tensile strength.

B)

The SAS System

The GLM Procedure

t Tests (LSD) for strength

Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	8.06
Critical Value of t	2.08596
Least Significant Difference	3.7455

Comparisons significant at the 0.05 level are indicated by ***.				
cotton_percent Comparison	Difference Between Means	95% Confidence Limits		
30 - 25	4.000	0.255	7.745	***
30 - 20	6.200	2.455	9.945	***
30 - 35	10.800	7.055	14.545	***
30 - 15	11.800	8.055	15.545	***
25 - 30	-4.000	-7.745	-0.255	***
25 - 20	2.200	-1.545	5.945	

Comparisons significant at the 0.05 level are indicated by ***.				
cotton_percent Comparison	Difference Between Means	95% Confidence Limits		
25 - 35	6.800	3.055	10.545	***
25 - 15	7.800	4.055	11.545	***
20 - 30	-6.200	-9.945	-2.455	***
20 - 25	-2.200	-5.945	1.545	
20 - 35	4.600	0.855	8.345	***
20 - 15	5.600	1.855	9.345	***
35 - 30	-10.800	-14.545	-7.055	***
35 - 25	-6.800	-10.545	-3.055	***
35 - 20	-4.600	-8.345	-0.855	***
35 - 15	1.000	-2.745	4.745	
15 - 30	-11.800	-15.545	-8.055	***
15 - 25	-7.800	-11.545	-4.055	***
15 - 20	-5.600	-9.345	-1.855	***
15 - 35	-1.000	-4.745	2.745	

From the above SAS output we can conclude that 2 pairs of the means are not significantly different. The attached do-by-hand work shows that the difference in means between $Y_1 and\ Y_5$, and $Y_2 and\ Y_3$ are not significantly different when using the Fischer LSD method.

The SAS System

The GLM Procedure

Tukey's Studentized Range (HSD) Test for strength

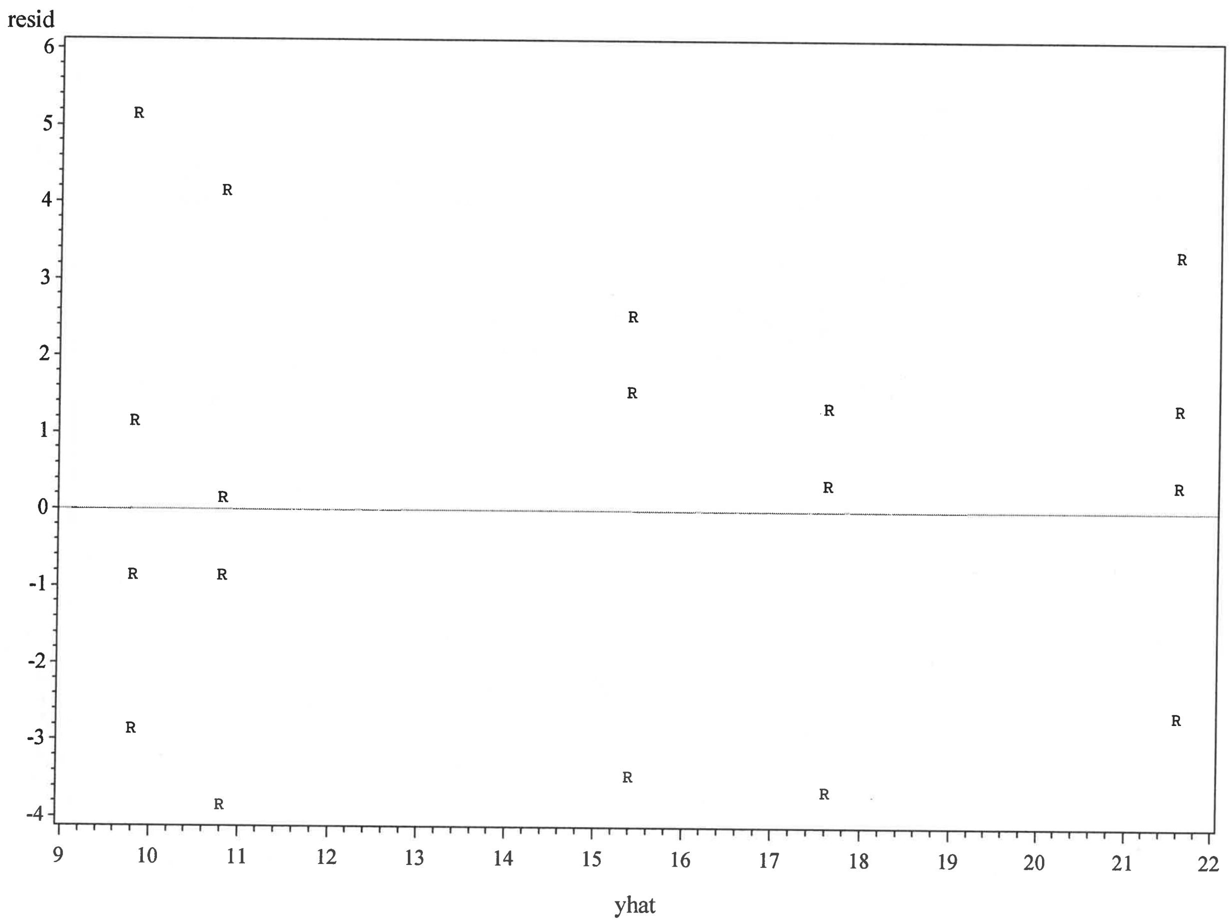
Alpha	0.05
Error Degrees of Freedom	20
Error Mean Square	8.06
Critical Value of Studentized Range	4.23186
Minimum Significant Difference	5.373

Comparisons significant at the 0.05 level are indicated by ***.				
cotton_percent Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
30 - 25	4.000	-1.373	9.373	
30 - 20	6.200	0.827	11.573	***
30 - 35	10.800	5.427	16.173	***
30 - 15	11.800	6.427	17.173	***
25 - 30	-4.000	-9.373	1.373	
25 - 20	2.200	-3.173	7.573	
25 - 35	6.800	1.427	12.173	***
25 - 15	7.800	2.427	13.173	***
20 - 30	-6.200	-11.573	-0.827	***
20 - 25	-2.200	-7.573	3.173	
20 - 35	4.600	-0.773	9.973	
20 - 15	5.600	0.227	10.973	***
35 - 30	-10.800	-16.173	-5.427	***
35 - 25	-6.800	-12.173	-1.427	***
35 - 20	-4.600	-9.973	0.773	
35 - 15	1.000	-4.373	6.373	
15 - 30	-11.800	-17.173	-6.427	***
15 - 25	-7.800	-13.173	-2.427	***
15 - 20	-5.600	-10.973	-0.227	***
15 - 35	-1.000	-6.373	4.373	

From the Tukey test we can see that 4 pairs of means are not significant. The attached do-by-hand work shows that the difference in means between $Y_1 and\ Y_5$, $Y_2 and\ Y_3$, $Y_2 and\ Y_5$, $Y_3 and\ Y_4$, are not significantly different when using the Fischer LSD method.

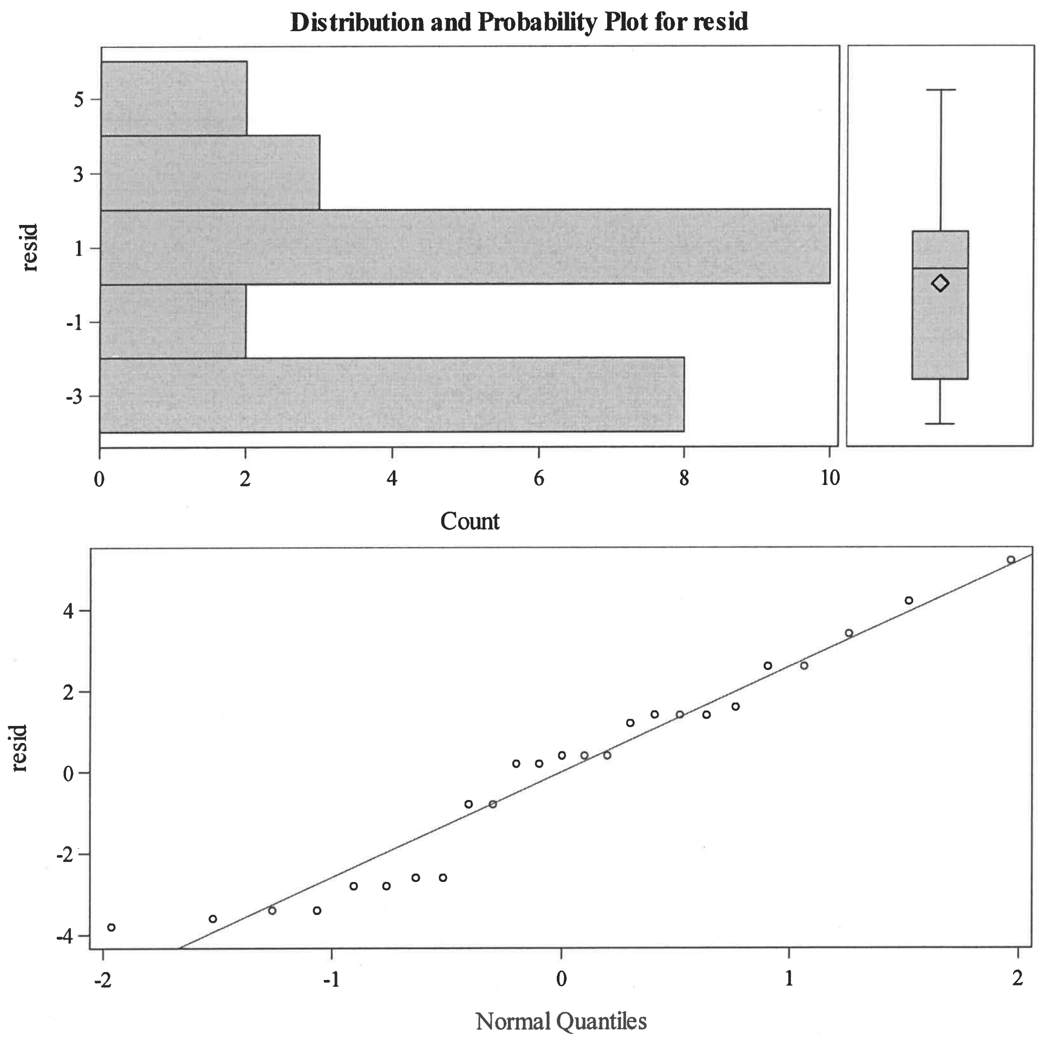
C)

Levene's Test for Homogeneity of strength Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
percent	4	91.6224	22.9056	0.45	0.7704
Error	20	1015.4	50.7720		



From the above SAS outputs, we can see that the F-Statistic from the Levene Test for Homogeneity is 0.45 with 4 and 20 degrees of freedoms. The corresponding P-Value is 0.7704 > $\alpha = 0.05$. From this test we can conclude that the residuals have equal variance. Additionally, the plot shows no clear pattern when we plot residuals against the predicted values. From both the plot and the Levene test we can conclude that the residuals have equal variance.

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.943868	**Pr < W**	0.1818
Kolmogorov-Smirnov	**D**	0.162123	**Pr > D**	0.0885
Cramer-von Mises	**W-Sq**	0.080455	**Pr > W-Sq**	0.2026
Anderson-Darling	**A-Sq**	0.518572	**Pr > A-Sq**	0.1775



The normality tests all have P-Values larger than 0.05. From this we can conclude that the residuals are normally distributed. The Q-Q plot also shows that the residuals are normally distributed.

3.14

Season	obs score										$Y_{i.}$	$\bar{Y}_{i.}$
Summer	83	85	85	87	90	88	88	84	91	90	871	87.1
Sholder	91	87	84	87	85	86	83				603	86.14
winter	94	91	87	85	87	91	92	86			713	89.125

$Y_{..} = 2187$

$\bar{Y}_{..}$ 87.84

$N = 25$ $a = 3$ $n_1 = 10$ $n_2 = 7$ $n_3 = 8$ $f = 22$

Source	df	SS	MS	F	P
Treatment	2	35.608	17.80	2.121	0.1437
Error	22	184.632	8.392		
Total	24	220.24			

$SSTO = \sum\sum y_{ij}^2 - \frac{Y_{..}^2}{N} = (83^2 + 85^2 + ... + 86)^2 - \frac{2187^2}{25} = 191539 - 191318.76 = 220.24$

$SSTR = \sum \frac{1}{n_i} Y_{i.}^2 - \frac{Y_{..}^2}{N} = \frac{1}{10}(871^2) + \frac{1}{7}(603)^2 + \frac{1}{8}(713)^2 - \frac{2187^2}{25} = 191354.37 - 191318.76 = 35.608$

$SSE = SSTO - SSTR = 220.24 - 35.608 = 184.632$

$H_0: \mu_{summer} = \mu_{sholder} = \mu_{winter}$ vs H_1: At least 1 pair not equal

Since p-value $= .1437 > .05 = \alpha$ we fail to reject H_0 and conclude all means are equal

b) Tukey $T = \frac{1}{\sqrt{2}} q_{\alpha}(a, f) \sqrt{MSE\left(\frac{1}{n_i} + \frac{1}{n_{i'}}\right)}$

$= \frac{1}{\sqrt{2}} \underset{3.55}{q_{.05}(3, 22)} \sqrt{8.392\left(\frac{1}{n_i} + \frac{1}{n_{i'}}\right)}$

$|(\bar{Y}_{summer} - \bar{Y}_{shoulder})| = 0.96$ $T = 5.068/\sqrt{2} = 3.584$

$|(\bar{Y}_{summer} - \bar{Y}_{winter})| = 2.025$ $T = 4.878/\sqrt{2} = 3.449$

$|(\bar{Y}_{shoulder} - \bar{Y}_{winter})| = 2.985$ $T = 5.322/\sqrt{2} = 3.763$

The Levene Test gives us a F-Stat of 0.49 with 2,22 degrees of freedom. This corresponds to a p-value of 0.6201 $> .05 = \alpha$ so we conclude that the residuals have equal variance.

All of the normality tests have a p-value larger than $\alpha = 0.05$. From these results and looking at the Q-Q plot we can conclude the residuals are normally distributed.

3.14. I belong to a golf club in my neighborhood. I divide the year into three golf seasons: summer (June–September), winter (November–March), and shoulder (October, April, and May). I believe that I play my best golf during the summer (because I have more time and the course isn't crowded) and shoulder (because the course isn't crowded) seasons, and my worst golf is during the winter (because when all of the part-year residents show up, the course is crowded, play is slow, and I get frustrated). Data from the last year are shown in the following table.

Season	Observations									
Summer	83	85	85	87	90	88	88	84	91	90
Shoulder	91	87	84	87	85	86	83			
Winter	94	91	87	85	87	91	92	86		

(a) Do the data indicate that my opinion is correct? Use $\alpha = 0.05$.

(b) Analyze the residuals from this experiment and comment on model adequacy.

A) We have the following hypothesis

$$H_0: \mu_{summer} = \mu_{Sholder} = \mu_{Winter} \ vs \ H_1: at\ least\ one\ pair\ of\ \mu\ is\ not\ equal$$

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	35.6078571	17.8039286	2.12	0.1437
Error	22	184.6321429	8.3923701		
Corrected Total	24	220.2400000			

From the above SAS output we can see that the F-Statistics is 2.12 with 2 and 22 degrees of freedom. The corresponding P-Value is 0.1437. Since the P-Value is larger than $\alpha = 0.05$ we fail to reject the null hypothesis and conclude that with the data available we cannot conclude that the golf season has an affect on the mean golf score.

B)

Tukey's Studentized Range (HSD) Test for score

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	8.39237
Critical Value of Studentized Range	3.55259

Comparisons significant at the 0.05 level are indicated by *.**				
season Comparison	**Difference Between Means**	**Simultaneous 95% Confidence Limits**		
3 - 1	2.025	-1.427	5.477	
3 - 2	2.982	-0.784	6.749	
1 - 3	-2.025	-5.477	1.427	
1 - 2	0.957	-2.629	4.543	
2 - 3	-2.982	-6.749	0.784	
2 - 1	-0.957	-4.543	2.629	

From the Tukey simultaneous comparison at $\alpha = 0.05$ we can see that none of the differences in means are significantly different. We see the same results in the Scheffe Test below

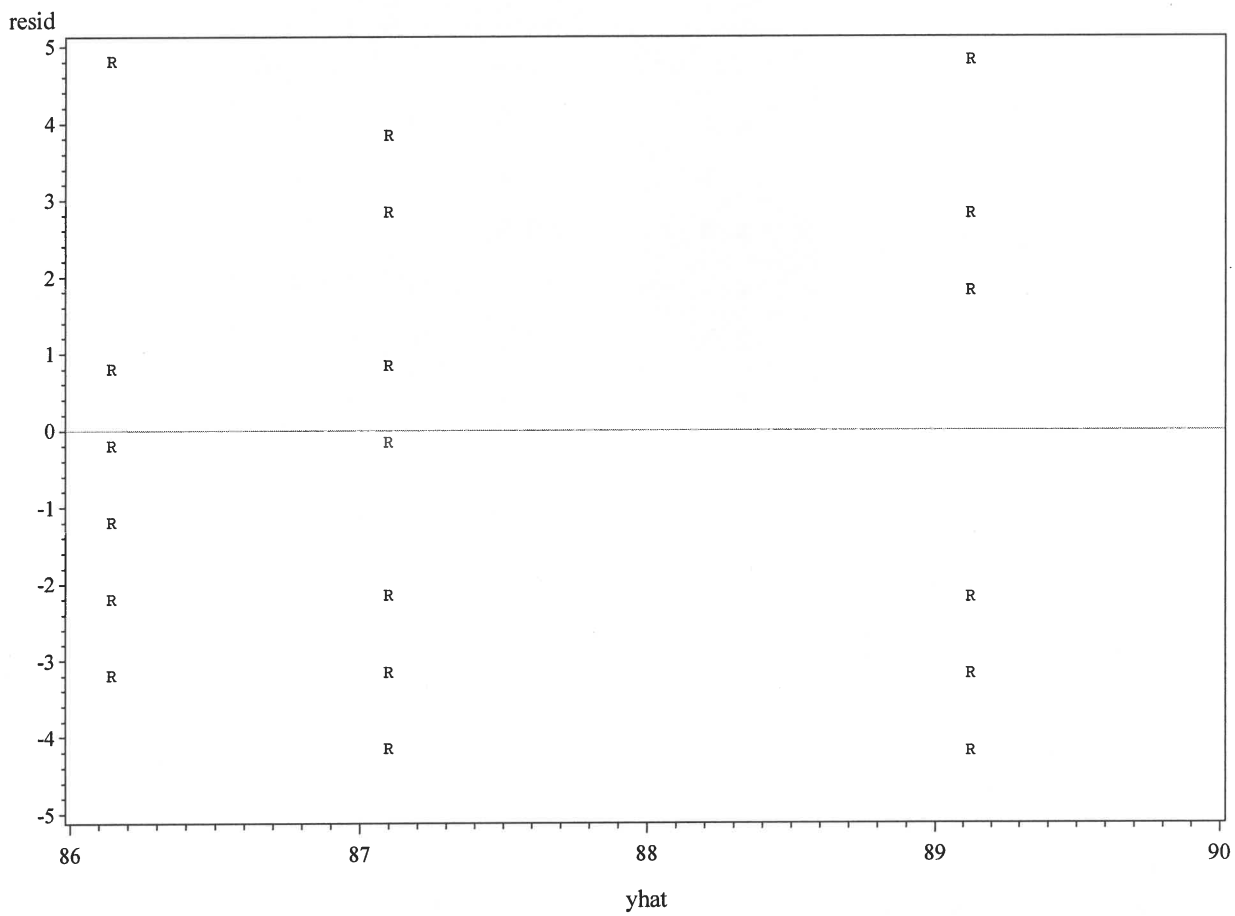
Scheffe's Test for score

Alpha	0.05
Error Degrees of Freedom	22
Error Mean Square	8.3923 7
Critical Value of F	3.4433 6

Comparisons significant at the 0.05 level are indicated by *.**				
season Comparison	**Difference Between Means**	**Simultaneous 95% Confidence Limits**		
3 - 1	2.025	-1.581	5.631	
3 - 2	2.982	-0.952	6.917	
1 - 3	-2.025	-5.631	1.581	
1 - 2	0.957	-2.789	4.704	
2 - 3	-2.982	-6.917	0.952	
2 - 1	-0.957	-4.704	2.789	

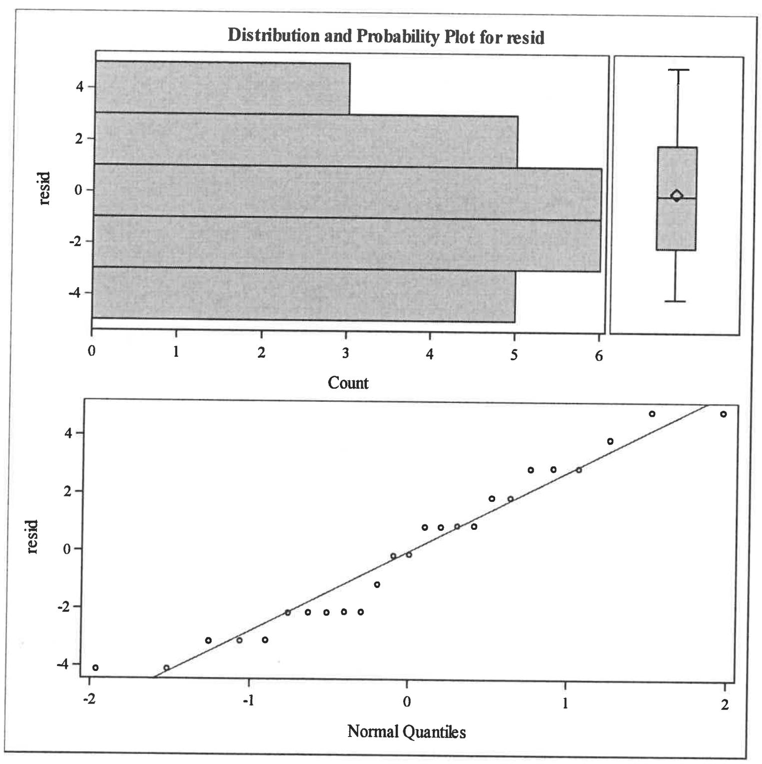
We will now check the model assumptions

Levene's Test for Homogeneity of score Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
season	2	50.4154	25.2077	0.49	0.6201
Error	22	1135.5	51.6135		



The above Levene Test for Homogeneity has a F-Statistics of 0.49 with 2 and 22 degrees of freedom. The corresponding P-Value is 0.6201 which is larger than $\alpha = 0.05$. From this test we can conclude that the residuals have a constant variance. The above plot of the residuals against the predicted values also does not display any clear pattern.

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.941209	Pr < W	0.1579
Kolmogorov-Smirnov	D	0.175514	Pr > D	0.0456
Cramer-von Mises	W-Sq	0.080374	Pr > W-Sq	0.2031
Anderson-Darling	A-Sq	0.500725	Pr > A-Sq	0.1977



All the above Normality Test have a P-Value larger than $\alpha = 0.05$. From the test results, and the above Q-Q plot we can conclude that the residuals are normally distributed.

3.18

Coating Type	Conductivity				$y_{i.}$	$\bar{y}_{i.}$
1	143	141	150	146	580	145
2	152	149	137	143	581	145.25
3	134	136	132	127	529	132.25
4	129	127	132	129	517	129.25

$y_{..} = 2207 \quad \bar{y}_{..} = 137.9375$

$N = 16, \quad a = 4 \quad n = 4$

$SSTO = \sum\sum y_{ij}^2 - \frac{y_{..}^2}{N} = (143^2 + 141^2 + \ldots + 129)^2 - \frac{2207^2}{16} = 305509 - 304428.06 = 1080.94$

$SSTR = \frac{1}{n}\sum y_{i.}^2 - \frac{y_{..}^2}{N} = \frac{1}{4}(580^2 + \ldots + 517^2) - \frac{2207^2}{16} = 305272.75 - 304428.06 = 844.69$

$SSE = SSTO - SSTR$ so $SSE = 236.25$

A)

Source	df	SS	MS	F	P-value
Treatment	3	844.69	281.56	14.302	2.881×10^{-4}
Error	12	236.25	19.69		
Total	15	1080.94			

From the above ANOVA table we can conclude that there is a difference in conductivity due to coating type

B) overall mean $= \hat{\mu} = \frac{2207}{16} = 137.94$

$\tau_1 = \bar{y}_{1.} - \bar{y}_{..} = 145 - 137.9375 = 7.0625$

$\tau_2 = \bar{y}_{2.} - \bar{y}_{..} = 145.25 - 137.9375 = 7.3125$

$\tau_3 = \bar{y}_{3.} - \bar{y}_{..} = 132.25 - 137.9375 = -5.6875$

$\tau_4 = \bar{y}_{4.} - \bar{y}_{..} = 129.25 - 137.9375 = -8.6875$

c) 95% CI of mean level 4

$$\bar{Y}_{i.} \pm t_{N-a}(\alpha/2)\sqrt{\frac{MSE}{n}}$$

$$= 129.25 \pm t_{12}(.025)\sqrt{\frac{19.69}{4}}$$

$$= 129.25 \pm 2.179\sqrt{\frac{19.69}{4}}$$

$[124.416, 134.084]$

99% CI for $\mu_1 - \mu_4$

$$(\bar{Y}_{1.} - \bar{Y}_{4.}) \pm t_{N-a}\left(\frac{\alpha}{2}\right)\sqrt{2\frac{MSE}{n}}$$

$$= (145 - 129.25) \pm t_{12}(.005)\sqrt{2\left(\frac{19.69}{4}\right)}$$

$$= 15.75 \pm 3.055\sqrt{9.845}$$

$[6.1644, 25.336]$

d) $LSD = t_{\frac{\alpha}{2}}(N-a)\sqrt{\frac{2MSE}{n}}$

$$= t_{.025}(12)\sqrt{2\left(\frac{19.69}{4}\right)}$$

$$= 6.835$$

$|\bar{Y}_{1.} - \bar{Y}_{2.}| = 0.25$ *

$|\bar{Y}_{1.} - \bar{Y}_{3.}| = 12.75$

$|\bar{Y}_{1.} - \bar{Y}_{4.}| = 15.75$

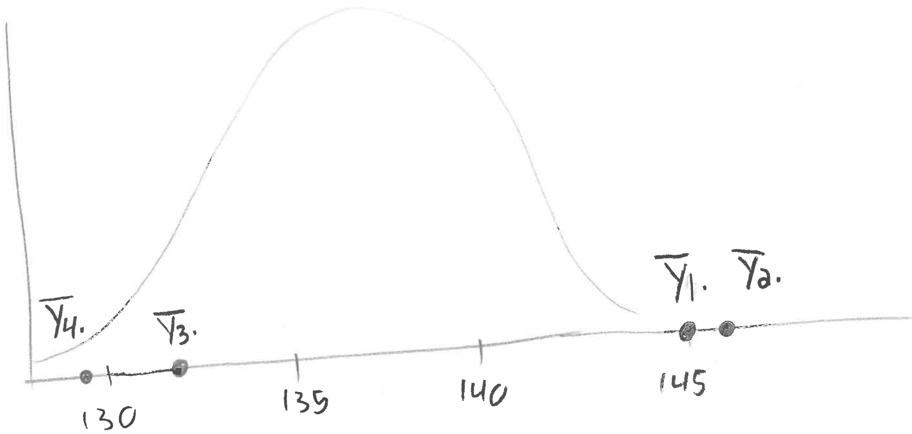
$|\bar{Y}_{2.} - \bar{Y}_{3.}| = 13$

$|\bar{Y}_{2.} - \bar{Y}_{4.}| = 16$

$|\bar{Y}_{3.} - \bar{Y}_{4.}| = 3$ *

From Fischer LSD we can see that $\bar{Y}_{1.} - \bar{Y}_{2.}$ and $\bar{Y}_{3.} - \bar{Y}_{4.}$ are <u>not</u> significant

e) $S_{\bar{y}_{i.}} = \sqrt{\frac{MSE}{n}} = \sqrt{\frac{19.69}{4}} = 2.219$



Conductivity

We can see that type 1 and 2 have the heighest conductivity

f) If we're using coating type 4 and we want to minimize conductivity the manufacture can use either type 3 or 4. By Fischer we can see that type 3 and 4 are not significantly different

3.19) From The attached SAS Code we can see the Levene Test has p-value of $0.1254 > .05 = \alpha$ so we conclude the error has constant variance

From the normality tests and Q-Q plot we can say the errors are normally distributed

3.18. A manufacturer of television sets is interested in the effect on tube conductivity of four different types of coating for color picture tubes. A completely randomized experiment is conducted and the following conductivity data are obtained:

Coating Type	Conductivity			
1	143	141	150	146
2	152	149	137	143
3	134	136	132	127
4	129	127	132	129

(a) Is there a difference in conductivity due to coating type? Use $\alpha = 0.05$.

(b) Estimate the overall mean and the treatment effects.

(c) Compute a 95 percent confidence interval estimate of the mean of coating type 4. Compute a 99 percent confidence interval estimate of the mean difference between coating types 1 and 4.

(d) Test all pairs of means using the Fisher LSD method with $\alpha = 0.05$.

(e) Use the graphical method discussed in Section 3.5.3 to compare the means. Which coating type produces the highest conductivity?

(f) Assuming that coating type 4 is currently in use, what are your recommendations to the manufacturer? We wish to minimize conductivity.

3.19. Reconsider the experiment from Problem 3.18. Analyze the residuals and draw conclusions about model adequacy.

A) We have the following hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 \ vs \ H_1: At\ least\ one\ pair\ of\ means\ is\ not\ equal$$

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	844.687500	281.562500	14.30	0.0003
Error	12	236.250000	19.687500		
Corrected Total	15	1080.93750 0			

From the above SAS output we can see the F-Statistic is 14.30 with 3 and 12 degrees of freedom. The corresponding P-Value is .0003. Since the P-Value is .0003 which is less than α = 0.05 we can conclude that not all the means are equal and that there is a difference in conductivity due to the coating used.

B) Overall mean:

$$\hat{\mu} = \frac{2207}{16} = 137.94$$

Treatment effects:

$$\tau_1 = \bar{Y}_{1.} - \bar{Y}_{..} = 145 - 137.9375 = 7.0625$$
$$\tau_2 = \bar{Y}_{2.} - \bar{Y}_{..} = 145.25 - 137.9375 = 7.3125$$
$$\tau_3 = \bar{Y}_{3.} - \bar{Y}_{..} = 132.25 - 137.9375 = -5.6875$$
$$\tau_4 = \bar{Y}_{4.} - \bar{Y}_{..} = 129.25 - 137.9375 = -8.6875$$

C) 95% Confidence Level for μ_4 is:

$$\bar{Y}_{i\cdot} \pm t_{N-a\left(\frac{\alpha}{2}\right)}\sqrt{\frac{MSE}{n}}$$

$$129.25 \pm t_{12\,(0.025)}\sqrt{\frac{19.69}{4}}$$

$$129.25 \pm 2.179\sqrt{\frac{19.69}{4}}$$

$$124.416 \leq \mu_4 \leq 134.084$$

99% Confidence Interval for $\mu_1 - \mu_4$:

$$\bar{Y}_{1\cdot} - \bar{Y}_{4\cdot} \pm t_{N-a\left(\frac{\alpha}{2}\right)} \sqrt{2\frac{MSE}{n}}$$

$$145 - 129.25 \pm t_{12,(.005)} \sqrt{2\frac{19.69}{4}}$$

$$15.75 \pm 3.055\sqrt{9.875}$$

$$6.1644 \leq \mu_1 - \mu_4 \leq 25.336$$

D)

t Tests (LSD) for conductivity

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	19.687 5
Critical Value of t	2.1788 1
Least Significant Difference	6.836

Comparisons significant at the 0.05 level are indicated by *.**				
coating_type Comparison	**Difference Between Means**	**95% Confidence Limits**		
2 - 1	0.250	-6.586	7.086	
2 - 3	13.000	6.164	19.836	***
2 - 4	16.000	9.164	22.836	***
1 - 2	-0.250	-7.086	6.586	
1 - 3	12.750	5.914	19.586	***
1 - 4	15.750	8.914	22.586	***
3 - 2	-13.000	-19.836	-6.164	***
3 - 1	-12.750	-19.586	-5.914	***
3 - 4	3.000	-3.836	9.836	
4 - 2	-16.000	-22.836	-9.164	***

Comparisons significant at the 0.05 level are indicated by ***.				
coating_type Comparison	Difference Between Means	95% Confidence Limits		
4 - 1	-15.750	-22.586	-8.914	***
4 - 3	-3.000	-9.836	3.836	

Tukey's Studentized Range (HSD) Test for conductivity

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	19.687 5
Critical Value of Studentized Range	4.1985 1
Minimum Significant Difference	9.3145

Comparisons significant at the 0.05 level are indicated by ***.				
coating_type Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
2 - 1	0.250	-9.065	9.565	
2 - 3	13.000	3.685	22.315	***
2 - 4	16.000	6.685	25.315	***
1 - 2	-0.250	-9.565	9.065	
1 - 3	12.750	3.435	22.065	***
1 - 4	15.750	6.435	25.065	***

Comparisons significant at the 0.05 level are indicated by ***.				
coating_type Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
3 - 2	-13.000	-22.315	-3.685	***
3 - 1	-12.750	-22.065	-3.435	***
3 - 4	3.000	-6.315	12.315	
4 - 2	-16.000	-25.315	-6.685	***
4 - 1	-15.750	-25.065	-6.435	***
4 - 3	-3.000	-12.315	6.315	

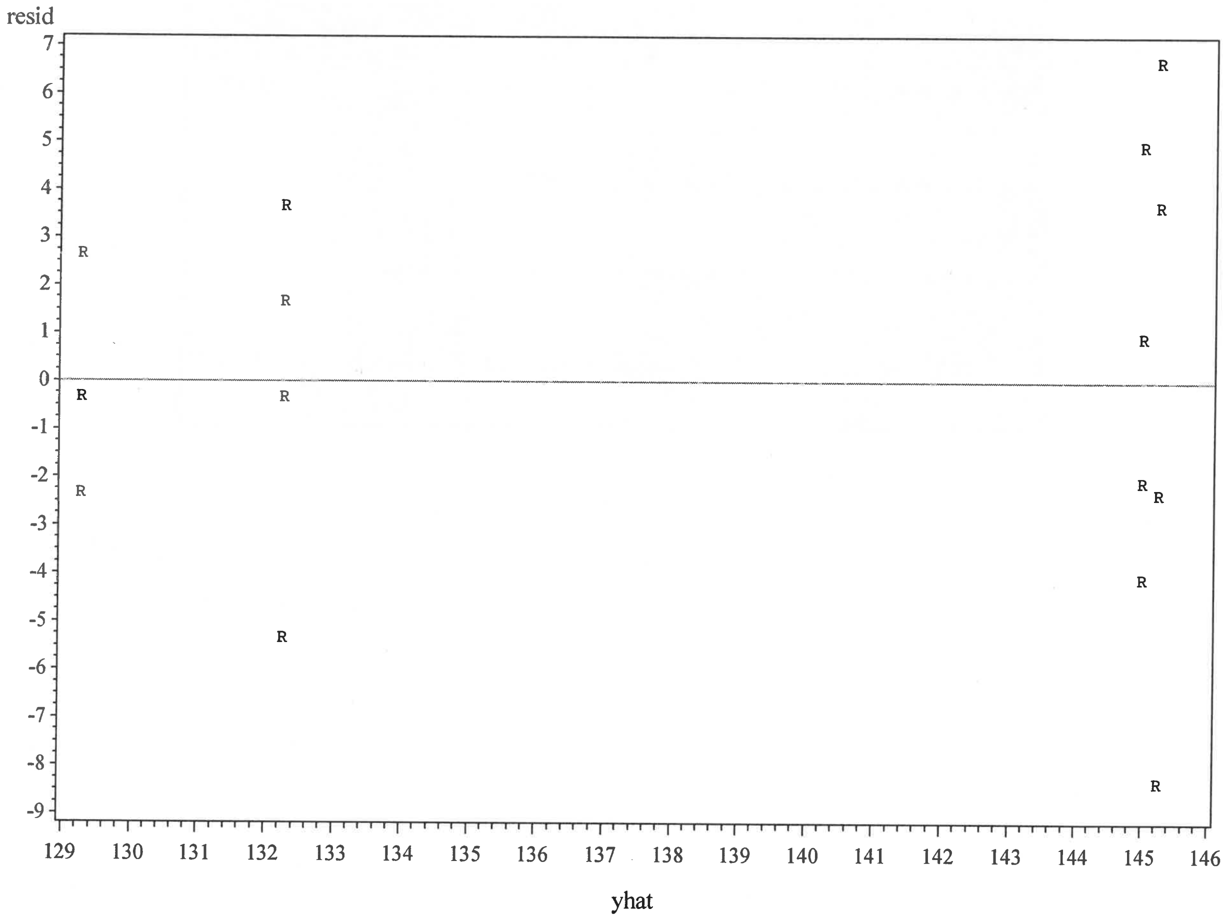
From the above SAS output we can see that $\bar{Y}_{1.} - \bar{Y}_{2.}$ and $\bar{Y}_{3.} - \bar{Y}_{4.}$ are not significantly different using the Fischer LSD method and the Tukey simultaneous comparison.

E) See attached do-by-hand for sketch and interpretation

F) If coating type 4 is being used and we want to minimize conductivity I would recommend the manufacturer keep using coating 4. From the Fischer LSD test and Tukey Simultaneous comparison we can see that the mean difference $\bar{Y}_{3.} - \bar{Y}_{4.}$ is not significantly different.

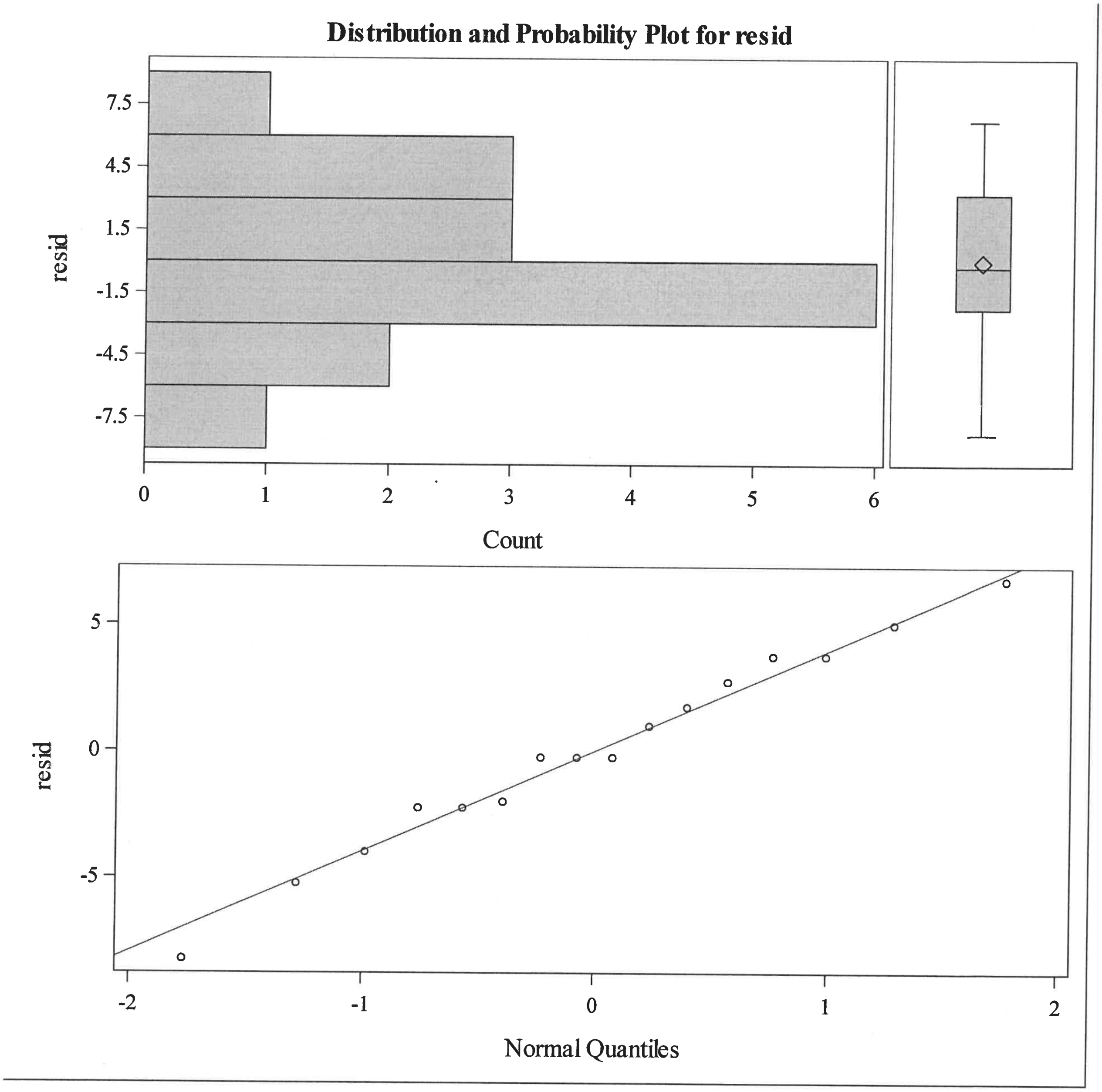
3.19)

Levene's Test for Homogeneity of conductivity Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
coating_type	3	1987.5	662.5	2.34	0.1254
Error	12	3403.6	283.6		



From the above SAS output we can see the Levene Test has a F-Statistic of 2.34 with 3 and 12 degrees of freedom. The corresponding P-Value is 0.1254. This P-Value is greater than $\alpha = 0.05$. From this test and the above residual plot, we can conclude that the residuals have equal variance.

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.984219	Pr < W	0.9882
Kolmogorov-Smirnov	D	0.099886	Pr > D	>0.1500
Cramer-von Mises	W-Sq	0.023381	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq	0.150853	Pr > A-Sq	>0.2500



The tests for normality all have P-Values larger than $\alpha = 0.05$. From these tests and the Q-Q plot we can say the residuals are normally distributed.