Statistics 621 Waiver Exam

August 29, 1999

Name_____ **SS#** _____

This is an **open-book** test; you are allowed to bring reference material with you. You have **two hours** for the exam. The computer output associated with one or more items should be considered an essential part of the questions. The multiple-choice questions are equally weighted. Please also note the following:

- **Fill in your name and student id number** above **and** on the answer form.
- **Mark the "bubbles"** under your name and student id number on the form.
- Choose **one best answer** by marking the item on the answer form.
- Mark the answer form using only a **#2 pencil**. Erase all changes completely.

Turn in **only** the answer form; you may keep the test. Solutions for the exam will be posted on the Statistics 608 web page in a day or two. You should mark your exam copy with your choices in order to see how well you did. The list of those passing this exam will be available in 111 Vance.

Question 1. Mark your solution form A.

(Questions 2-8) A telephone sales company handling outdoor clothing (like LL Bean) studied the sales generated by a call-handling center. The company fit a regression model relating sales per hour in one of its call centers (Sales/Hour, in dollars) to the number of incoming calls during the hour. Both variables are measured hourly. The company obtained this hourly data by collecting the data for the hours noon – 4 p.m. over 25 past weekdays, for a total of 100 observations.

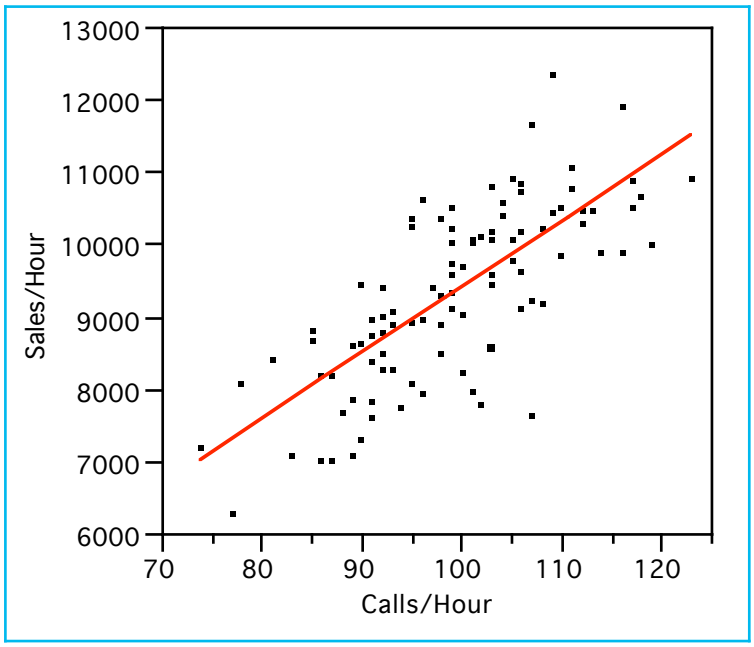
(2) The fitted model implies that

(a) The call center generates about $310 per hour in sales.
(b) Each telephone service person generates about $91 in sales per hour.
(c) About 91 calls come in each hour on average to this call center.
(d) Each call generates $91 in sales, on average.
(e) About 55% of the calls to this call center are profitable.

(3) During an hour with 100 calls, the level of sales generated should be in the range

(a) $ 310 ± $ 825
(b) $ 3100 ± $1600
(c) $ 9400 ± $1600
(d) $12200 ± $1600
(e) Cannot be identified without the RMSE of this model.

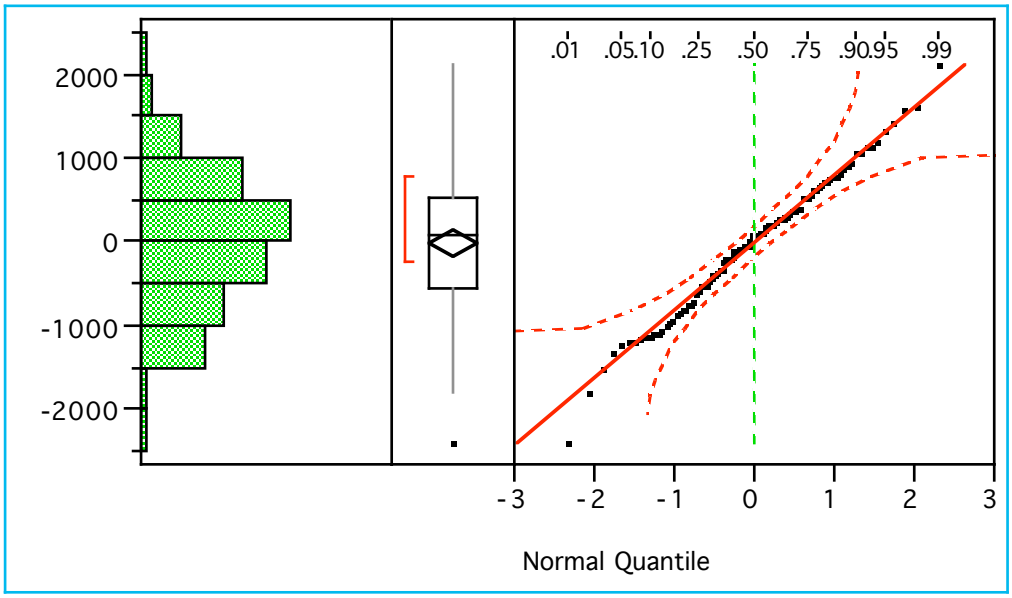
Sales/Hour By Calls/Hour



Sales/Hour = 310 + 91 Calls/Hour

RSquare			0.55	
Observations			100	
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	310	825	0.38	0.7077
Calls/Hour	91	8	11.00	<.0001

Residuals Sales/Hour



(4) The most negative outlier for this regression
(a) Implies that the data are not a sample from a normal population.
(b) Is very leveraged and should be excluded from the fitted model.
(c) Is very influential and should be excluded from the fitted model.
(d) Is not very aberrant and is typical of the variation around the fit.
(e) Is a clear coding error and should be excluded from the model.

(5) Removing the most negative outlier from the fit would clearly
(a) Cause the intercept of the fitted model to become smaller.
(b) Cause the slope of the fitted model to become smaller.
(c) Reduce the size of the residual standard deviation.
(d) Increase the RMSE of the resulting model.
(e) Have no effect upon the p-value for the slope of the fitted model.

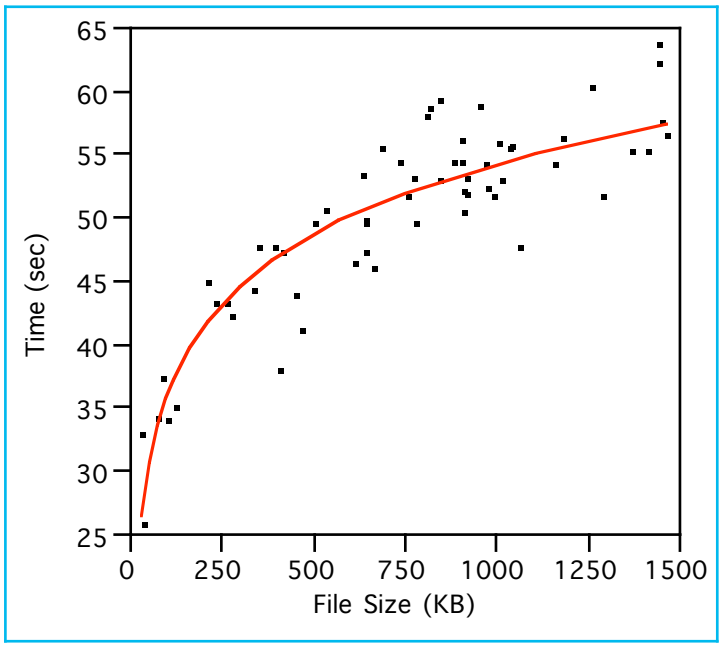
(6) Given a model with a fitted $R^2 = 0.55$ and one predictor as found in the above regression, how many observations are needed for such a fitted model to represent a significant proportion of the total variation in the response?
(a) About 5.
(b) About 25.
(c) About 50.
(d) About 100.
(e) Cannot be determined from the available information.

(7) This model can be interpreted to mean that variation in the number of calls "explains" significant variation in the amount of hourly sales because
(a) The overall F-ratio is significantly large.
(b) The absolute value of the t-ratio for the slope of calls per hour is larger than 2.
(c) The p-value for the slope for calls per hour is less than 0.05.
(d) The R^2 statistic is large given only one slope was fitted to 100 observations.
(e) All of the above.

(8) What diagnostic procedure would be most useful to add to this analysis?
(a) A normal quantile plot of the residuals.
(b) A plot of the residuals on the fitted values to check for changing variances.
(c) Check that the response (sales per hour) has a normal distribution.
(d) Plot the residuals over time and compute the DW statistic.
(e) Look for outliers in the leverage plot for calls per hour.

(Questions 9-15) A small firm tested the performance of its intranet by measuring the length of time required to transfer 60 files. These files ranged in size from about 20,000 characters (20 KB) up to about 1.5 million characters (1.5 MB). The files were transferred over the network during the day using a standard internet browser. An analysis of the transfer times follows.

Time (sec) By File Size (KB)

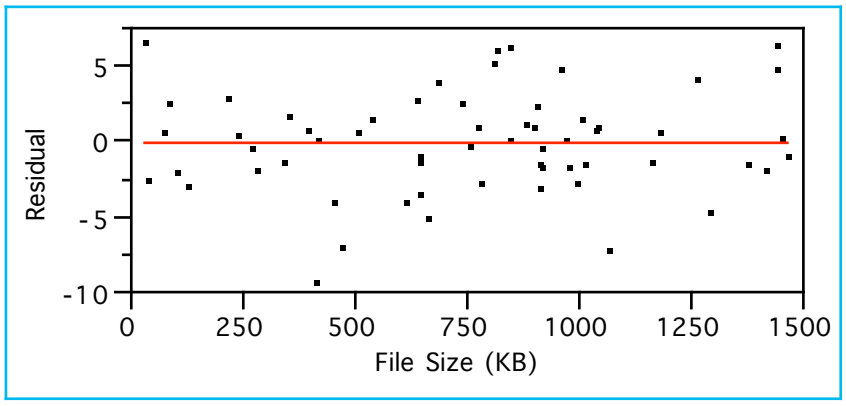


Transformed Fit

Time (sec) = 1.28 + 7.51 Log(File Size (KB))

Rsquare	0.81
Root Mean Square Error	3.39

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.28	3.27	0.39	0.70
Log(File Size (KB))	7.51	0.51	14.7	0.00



(9) The fitted model implies that the use of the natural log of the file size as a predictor
(a) Does not explain significant variation in the time required to transfer the files.
(b) Explains significant variation in the time required to transfer the files.
(c) Is unreliable since the files vary in size.
(d) Explains less than half of the variation in transfer times.
(e) Is flawed and should be replaced in the model by the actual file size.

(10) The intercept term in the fitted model indicates that
(a) It takes about 1.28 seconds to transfer a file of no characters.

(b) It takes about 1.28 seconds to transfer a file of 1KB (1,000 characters).
(c) Short files take 28% longer to transfer than larger files.
(d) The model is flawed since the confidence interval for the intercept includes zero.
(e) Cannot be interpreted because of the use of the log transformation.

(11) The company occasionally needs to distribute a broadcast message. It does this by attaching the message to another file which is then distributed through the system. The addition of the message increases the file size by 100KB. Should the company attach the message to a 100KB file or to 1,000KB file?
(a) To the large file since it would makes up only 9% of the size of the combined file.
(b) To the small file since it would make up 50% of the size of the combined file.
(c) It does not matter, since either choice results in the same increase in time to send the file.
(d) To the small file since this choice will result in the smaller increase in time.
(e) To the large file since this choice will result in the smaller increase in time.

(12) From the fitted model, the company should estimate the length of time required to transfer a file which is 1,000 KB (1,000,000 characters) to be
(a) 7,500 seconds
(b) 750 seconds
(c) 53 seconds
(d) 7.51 seconds
(e) 1.28 seconds

(13) When the company ran the test, sending the 1,000 KB file, the observed length of time to send the file was about 9 seconds less than that predicted by the model. This difference implies
(a) Little, since the model only captures 81% of the variation in transfer time.
(b) That this transfer happened faster than the model predicts.
(c) That this transfer is within the level of error expected under the model.
(d) Little, since the file is so large and unlike those used to develop the model.
(e) Little, since this prediction lies within the 95% prediction interval at 1,000 KB.

(14) The company has been pleased with the results of its modeling effort and plans to expand the model, adding a variable for the number of active users. The initial connection and file transfer both take longer as the number of users on the system increases. Which of the following modifications to the model captures this effect most completely:
(a) Add a variable for the number of users to the fitted regression model.
(b) Add a variable for the number of users and its interaction with file size to the model.
(c) Add a categorical variable to the model indicating the time of day when measured.
(d) Add a categorical variable indicating the day of the week to the model.
(e) Leave the fitted equation alone since it already explains significant variation in time.

(Questions 15-22) An auto manufacturer was interested in pricing strategies for a new vehicle it plans to introduce in the coming year. The analysis that follows considers how other manufacturers price their vehicles. The analysis begins with the correlation of price with certain features of the auto, particularly those relating to the performance of the vehicle. Among the predictors, the displacement measures the size of the engine in cubic inches, and HP/Pound is the ratio of the

horsepower to the weight of the car. The data are a collection of 109 models available in a given market year, as studied in class. Some of these correlations are given in the following table.

Correlations

Variable	Price	Weight(lb)	Horsepower	Displacement	HP/Pound
Price	1.00	0.70	0.74	0.54	0.47
Weight(lb)	0.70	1.00	0.76	0.83	0.30
Horsepower	0.74	0.76	1.00	0.79	0.84
Displacement	0.54	0.83	0.79	1.00	0.48
HP/Pound	0.47	0.30	0.84	0.48	1.00

In addition, the manufacturer also considered a regression model for the price, which is measured in dollars (US). The model fit to price is summarized next.

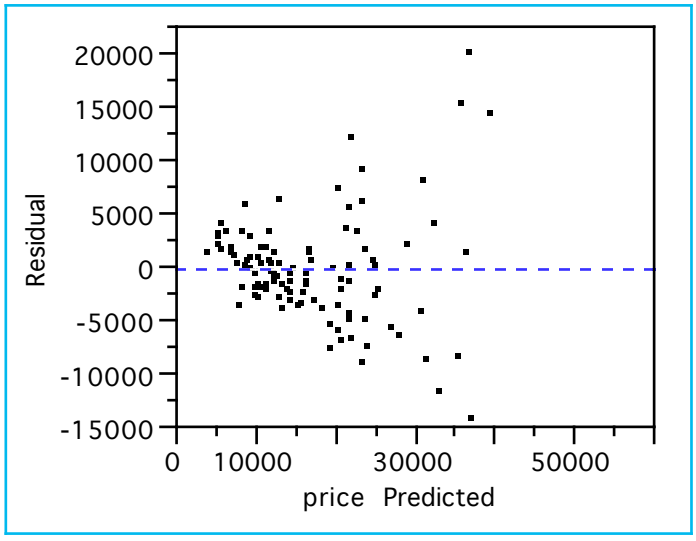
Response: Price

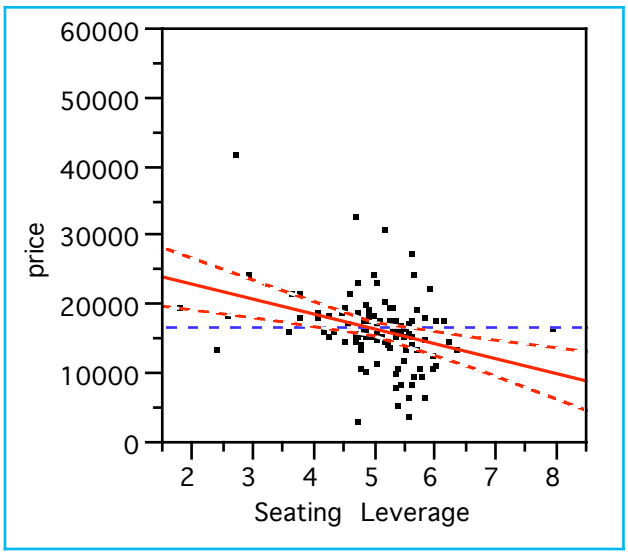
RSquare	0.74
Root Mean Square Error	5121
Observations	109

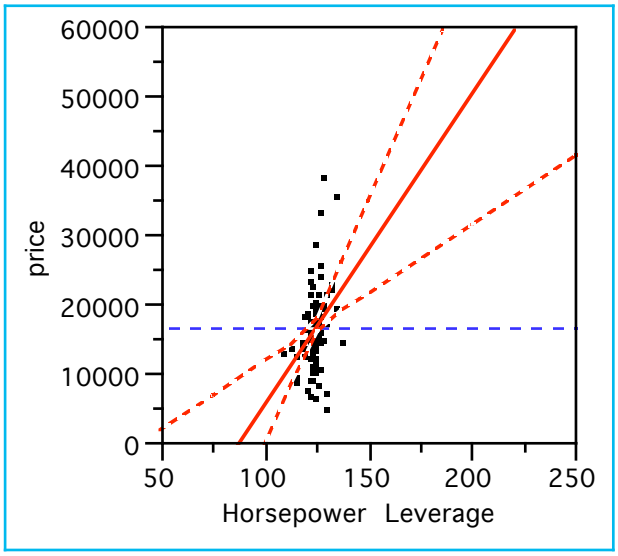
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	26811	15173	1.77	0.0802
Weight(lb)	-1	5	-0.14	0.8865
Seating	-2116	587	-3.60	0.0005
Horsepower	455	124	3.67	0.0004
Displacement	-99	20	-4.90	<.0001
HP/Pound	-1112390	370706	-3.00	0.0034
Cylinders	2108	848	2.49	0.0145

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	7628359386	1.2714e9	48.5
Error	102	2674916961	26224676	**Prob>F**
C Total	108	1.03033e10		<.0001







(15) Considered marginally, manufacturers of the studied cars charge on average
(a) More for cars with larger engines (higher displacement).
(b) Less for cars with larger engines (higher displacement).
(c) About the same regardless of engine size (displacement).
(d) More for cars with larger engines (higher displacement) if the weight is fixed.
(e) Cannot be answered without a plot of all of the variables.

(16) The company plans to offer two virtually identical models of this car, with the only difference being the number of cylinders in the engine, 4 cylinders versus 6. Based on the fitted model as shown, most companies would charge about
(a) $4200 more for the six-cylinder version.
(b) $2100 more for the six-cylinder version.
(c) $850 more for the six-cylinder version.
(d) The same for both models.
(e) Cannot be determined without the correlation between cylinders and price.

(17) The combination of predictors in this fitted model together
(a) Explains a significant amount of the variability in the price of cars.
(b) Does not predict significant variation in the price of cars.
(c) Implies that manufacturers price cars without regard to engine characteristics.
(d) Accurately predicts 26% of the observations.
(e) Accurately predicts 74% of the observations.

(18) The substantial size of the negative coefficient for the power-to-weight ratio (labeled HP/Pound)
(a) Implies that cars with a high power to weight ratio are expensive given their weight.
(b) Is not significantly different from zero and therefore does not merit interpretation.
(c) Is probably due to collinearity among the predictors in the fit.
(d) Represents an interaction term and is not useful without categorical variables.
(e) Is small relative to its standard error and unimportant to the fitted model.

(19) Two leverage plots, one for *Seating* and one for *Horsepower* are shown with the model summary. These leverage plots as shown imply that
(a) The precision of the coefficient for *Horsepower* has been reduced by collinearity.
(b) The precision of the coefficient for *Seating* has been reduced by collinearity.
(c) Collinearity has seriously inflated the standard errors of all slopes in the model.
(d) *Horsepower* is positively correlated with *Price*.
(e) One outlying observation has significantly decreased the slope for *Seating*.

(20) The plot of the model's residuals on fitted values shown with the model summary suggests that
(a) The observations are clustered and not independent.
(b) The error variation is not constant, violating an assumption.
(c) The error terms are not normally distributed, violating an assumption.
(d) The model requires an interaction term to stabilize the variation.
(e) The model requires a nonlinear predictor to capture the omitted variation.

(21) When used for prediction, the standard 95% prediction interval for a new model car will
(a) Include only 74% of the observed data.
(b) Be inaccurate since the model is plagued by problems of collinearity.
(c) Be too wide for inexpensive cars and too narrow for expensive cars.
(d) Have the form of (predicted price in dollars) ± $5121.
(e) Be two long (or too wide) for any practical use or interpretation.

(22) As an additional diagnostic, an analyst computed the Durbin-Watson statistic for this fitted regression. The value found was 1.6. Based on this calculation, we can conclude that
(a) The data are autocorrelated and thus dependent over model years.
(b) The data are dependent in some general nonlinear fashion.
(c) The data are independent observations.
(d) The data lack constant variance and are not homoscedastic.
(e) The residuals do not track when cars are ordered as in the data file.

(Questions 23-34) A sample of 43 active women and 44 active men who exercise at a local gym was used to study differences between men and women in physical activity. Each individual ran on a treadmill of increasing tilt until exhaustion. The duration in seconds (Duration_Sec) of each effort was recorded. In addition, the study recorded the maximum rate of oxygen use (VO_2 max) and the maximum observed heart rate (HR max, in beats per minute), as well as the Age (in years) and body mass index (BMI). Questions follow the output.

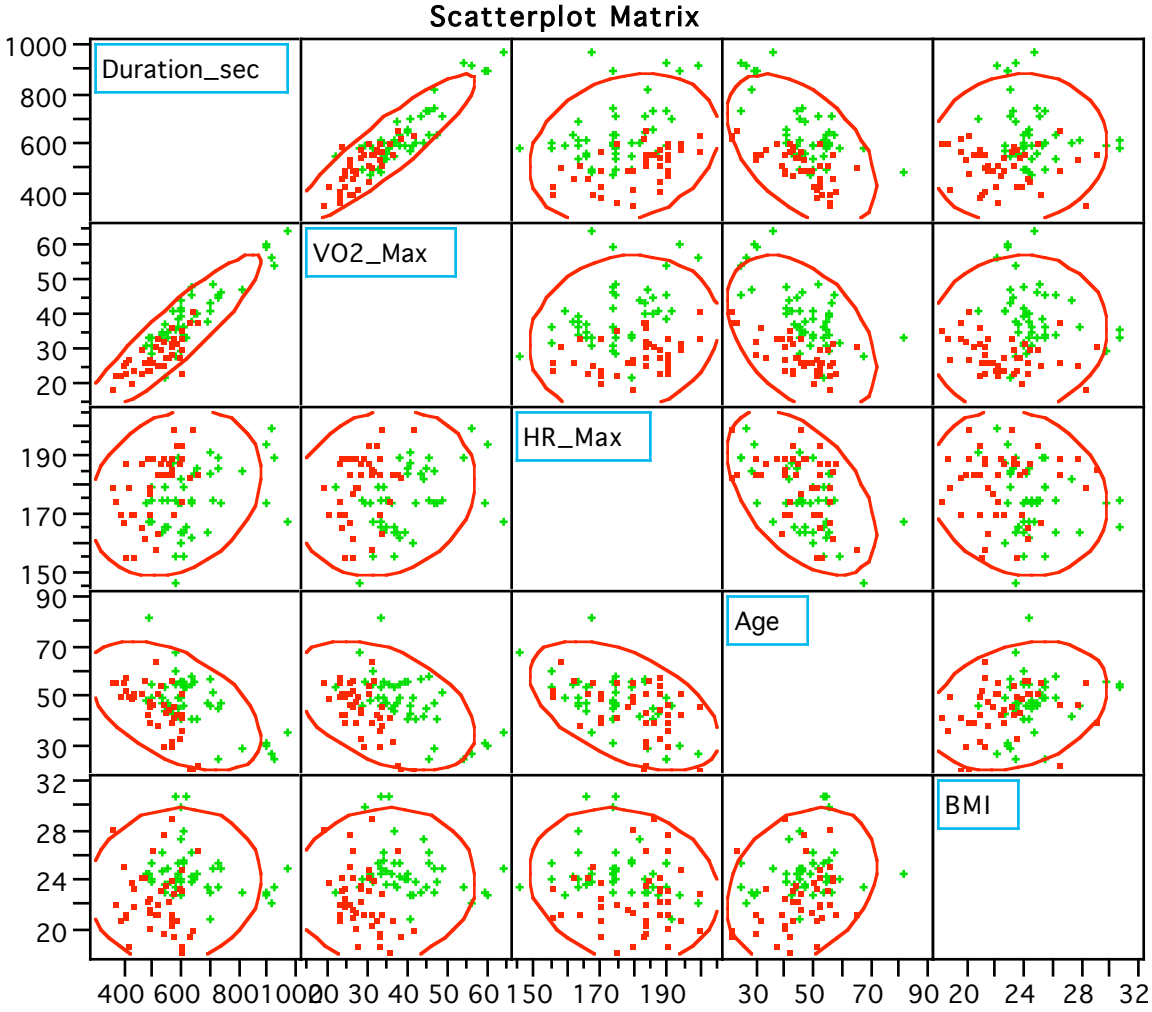
Summary of Duration_Sec, by Sex

Level	Number	Mean	Std Dev
female	43	500	81
male	44	650	110

Correlations

Variable	Duration_Sec	VO2_Max	HR_Max	Age	BMI
Duration_Sec	1.00	0.91	0.24	-0.49	0.08
VO2_Max	0.91	1.00	0.14	-0.42	0.07
HR_Max	0.24	0.14	1.00	-0.50	-0.16

Age	-0.49	-0.42	-0.50	1.00	0.27
BMI	0.08	0.07	-0.16	0.27	1.00



(23) The correlation summary implies that

(a) VO_2 max alone explains over 80% of the variation in duration.
(b) There is no collinearity among this collection of predictors.
(c) None of the predictors, used alone, will explain significant variation.
(d) BMI is useless to consider further in modeling duration.
(e) Men and women behave identically since the correlation matrix is symmetric.

(24) The scatterplot matrix

(a) Indicates that when adjusted for age, women are able to stay on the treadmill longer.
(b) Shows little beyond the information in the correlation table.
(c) Reveals extreme collinearity because of the narrow ellipse for duration and VO_2 max.
(d) Shows that all of the subjects are 20 to 30 years old.
(e) Shows that the maximum of VO_2 and of HR are redundant predictors.

MODEL 1

Response: Duration_Sec

RSquare	0.833
Root Mean Square Error	51.2
Observations	87

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-51.49	87.02	-0.59	0.56
Sex[female-male]	-3.22	7.75	-0.42	0.68
VO2_Max	11.58	0.82	14.08	0.00
HR_Max	1.29	0.53	2.45	0.02

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	1088844	362948	138.36
Error	83	217726	2623	**Prob>F**
C Total	86	1306570		<.0001

(25) Based on the fit of MODEL 1, if a woman increases her maximum heart rate by 10 beats per minute while retaining her maximum VO_2, then her time on the treadmill will
(a) Increase by about 13 seconds.
(b) Not change since *Sex* is not a significant predictor.
(c) Not change since the p-value of VO_2 max is so small.
(d) Increase by about 1.3 seconds.
(e) Decrease by about 30 seconds.

(26) MODEL 1 indicates for individuals of comparable maximum rates of oxygen uptake and heart rate that, on average in the population,
(a) Women are able to remain on the treadmill 3.2 sec longer than men.
(b) Men are able to remain on the treadmill 3.2 sec longer than women.
(c) Women are able to remain on the treadmill 6.4 sec longer than men.
(d) Men are able to remain on the treadmill 6.4 sec longer than women.
(e) Sex of the individual has little role in determining endurance.

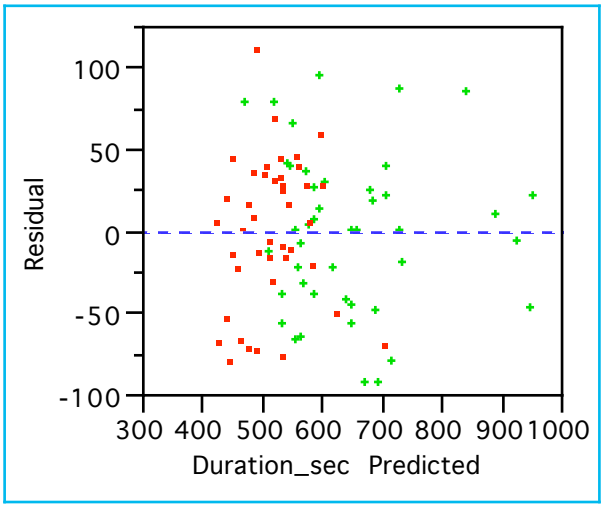
(27) Suppose we were able to repeat this regression analysis, but with four times as many men and four times as many women in the study (sampled from the same population). Then the model fit to this larger data set would reliably show which of the following characteristics?
(a) A much smaller value for the RMSE.
(b) A substantially increased value for R^2.
(c) A substantially decreased value for R^2.
(d) A negative slope for the *Sex* categorical predictor.
(e) A larger, more significant overall F-ratio.

(28) A local fitness coach who trains tri-athletes uses predictions from MODEL 1 to screen athletes before he accepts them for training. The endurance of one candidate was 405 seconds, whereas that of another was 425 seconds. Assuming both candidates are women with equal max VO_2 and max HR, then from this model the coach can conclude that the athlete with the lower time is

(a) Performing significantly better than the other athlete.
(b) Performing significantly worse than the other athlete.
(c) Performing slightly better than the other athlete.
(d) Performing slightly worse than the other athlete.
(e) Over-trained and will not be able to improve the current level of performance.

(29) Does MODEL 1 explain significantly more variation in duration time on the treadmill than a regression that uses only *Sex* and VO_2 as predictors?
(a) Yes, the t-ratio for maximum HR is larger than 2.
(b) Yes, the t-ratio for maximum VO_2 is larger than 2.
(c) Yes, the overall F-ratio for this model is very large and significant.
(d) No, the change in R^2 is too small to be significant.
(e) No, the t-ratio for *Sex* is less than 2 in absolute value.

(30) The following plot shows the residuals from MODEL 1. Men appear as small gray crosses +, and women are small dark dots. The points on the right side of the plot are predominantly gray crosses. This plot indicates that the
(a) Model violates the assumption of constant variance
(b) Model suffers from collinearity since the two groups overlap.
(c) Men tend to have larger predicted values than women.
(d) Model violates the assumption of normality and cannot be trusted.
(e) Observations for each sex are correlated and thus violate the assumed independence.



MODEL 2

Response: Duration_Sec

RSquare	0.85
Root Mean Square Error	48.55
Observations	87

Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	2700.68	1030.93	2.62	0.0105	0.00
Sex[female-male]	-10.78	7.75	-1.39	0.1680	2.21
VO2_Max	2.76	3.82	0.72	0.4716	45.96
HR_Max	-28.36	11.69	-2.43	0.0175	680.72
VO2_Max*VO2_Max	0.10	0.05	2.29	0.0244	41.39
HR_Max*HR_Max	0.08	0.03	2.55	0.0127	684.24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	1115634	223127	94.6559
Error	81	190936	2357	Prob>F
C Total	86	1306570		<.0001

(31) Does MODEL 2 offer predictions of duration that are significantly more accurate than those of MODEL 1?
(a) No, the change in R^2 is only about 2% and not important.
(b) Yes, R^2 increased when the two predictors were added to the fit.

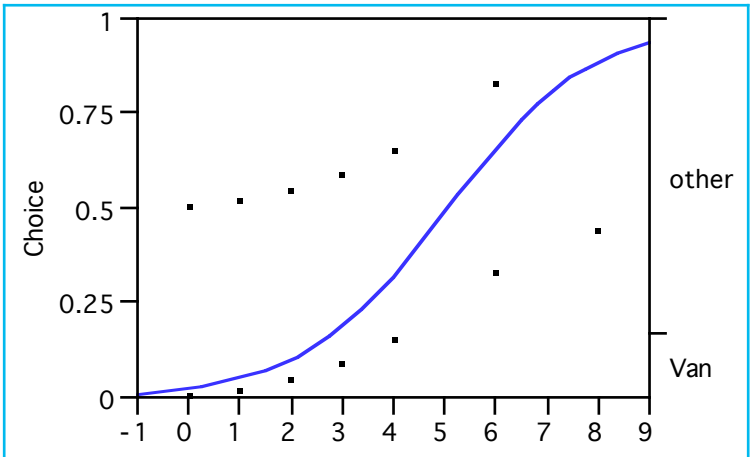
(c) No, the previously useful predictor VO2_Max is no longer relevant.
(d) Yes, both added predictors have significant coefficients.
(e) No, the change in the RMSE will not have much impact on the prediction intervals.

(32) In MODEL 2, the large VIF for max HR and its quadratic (product) term imply that
(a) These terms are unreliable and should be excluded from the fit.
(b) Outlying observations have grossly inflated the variance of these coefficients.
(c) The model violates the assumption of independence and must be discarded.
(d) Collinearity increases the SE for these, but the estimates remain significant.
(e) We cannot interpret these coefficient estimates since the SE's are so inflated.

(33) In MODEL 2, the quadratic term which is the square of the maximum VO_2 (labeled in the JMP output as VO2_Max*VO2_Max)
(a) Is not significant and hence does not merit interpretation.
(b) Implies that incremental effects of VO_2 become larger at larger levels of VO_2.
(c) Is not meaningful since the estimated slope for VO_2 itself is not significant in the fit.
(d) Cannot be interpreted since the VIF for this estimate is so large.
(e) Cannot be interpreted since the fitted model includes slopes that are not significant.

(34) Based on MODEL 2, is *Sex* an important predictor of duration in this treadmill test?
(a) Yes, its coefficient is quite large and cannot be ignored.
(b) Yes, otherwise the model would no longer distinguish male from female athletes.
(c) No.
(d) No, because the VIF for this term is the smallest (but for that of the intercept).
(e) No, because this model has too much collinearity to be interpretable.

(Questions 35-38) An automotive dealership has been keeping track of the sales choices of various type of customers. It would like to use this information to better direct the customer to a likely purchase more quickly without letting them wander away. The data used in this example are the sales preferences of 75 couples (male & female) who visited the dealership and purchased a vehicle. The following plot shows the results of a model for the preference for a van as opposed to purchasing an other type of car as a function of the number of children in the family of the couple. The "variable" or column labeled Choice has the value "Van" if the couple purchased a van, and has the value "other" otherwise. The column "Num_Children" indicates the number of children in the family (as indicated during their application for financing).



Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-3.6	0.7	26.4	<.0001
Num_Children	0.7	0.2	14.0	0.0002

(35) Based on the fitted model, does the number of children in the family as reported on the credit application appear to be related to the customers' preference for a van?
(a) No, the effect is in the right direction but not significantly large.
(b) No, the effect is near zero.
(c) No, the effect is in the wrong direction and not meaningful.
(d) Yes, the effect is significant and in the expected direction.
(e) We have too little data to evaluate the effect of number of children.

(36) Sales representatives at the auto dealership would like to steer clients quickly to the appropriate section of the car lot. Based on this model and knowledge of family size, what is the largest size family for which over half of those at this dealership still prefers something other than a van?
(a) 2 children
(b) 3 children
(c) 4 children
(d) 5 children
(e) 6 children

(37) The intercept term in the fitted model implies
(a) That families with no children are about 3 and a half times less likely to purchase a van.
(b) That families with children are about 3 and a half times more likely to purchase a van.
(c) That the probability for a van purchase with no children is slightly less than 0.03.
(d) The model is not well specified since the value is negative.
(e) Little, because it cannot be interpreted since it is too close to zero.

(38) From the fitted model, a family with two children is about
(a) Less likely to purchase a van than a family with one child.
(b) 50% more likely to purchase a van than a family with one child.
(c) Two times more likely to purchase a van than a family with one child.
(d) Three times more likely to purchase a van than a family with one child.
(e) Number of children has no effect.

(Questions 39-41) A company has developed a new type of razor with extra blades that are very sharp. To gauge consumer reaction to this new product, the company assembled a focus group of customers who use its traditional products. Each customer was given a razor to use. After using the razor, each member of the focus group rated the new model on several attributes; these attributes were combined to form an overall rating that ranged from 0 (dislike new razor) to 10 (razor is great). Of the 60 customers in the focus group, 30 were men and 30 were women. Within each sex, 10 of the customers had a high-school education, 10 had a college degree, and the remaining 10 had gone

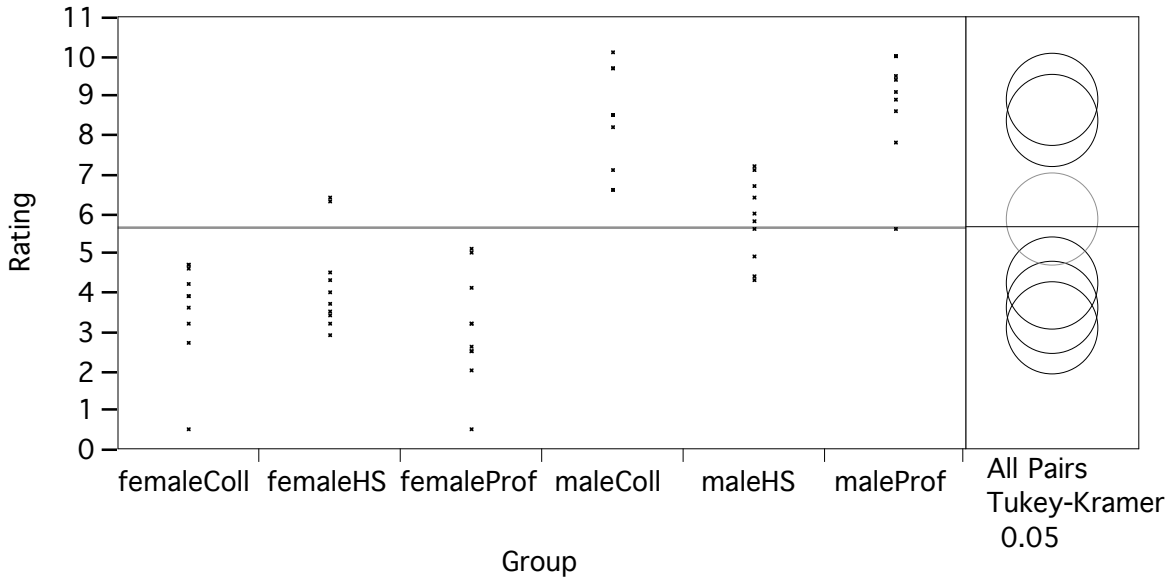
on to obtain a further professional degree (such as from medical school or business school). From written comments, analysts noted that women commented that the razor became dull while shaving their legs. Several men commented that the razor seemed to shave very, very close.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	307.26683	61.4534	38.4017
Error	54	86.41500	1.6003	Prob > F
C. Total	59	393.68183		<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Sex	1	1	247.66017	154.7607	<.0001
Education	2	2	11.97033	3.7401	0.0301
Education*Sex	2	2	47.63633	14.8838	<.0001



Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
femaleColl	10	3.60	0.40	2.80	4.40
femaleHS	10	4.22	0.40	3.42	5.02
femaleProf	10	3.07	0.40	2.27	3.87
maleColl	10	8.35	0.40	7.55	9.15
maleHS	10	5.84	0.40	5.04	6.64
maleProf	10	8.89	0.40	8.09	9.69

Std Error uses a pooled estimate of error variance

Comparisons for all pairs using Tukey-Kramer HSD

Abs(Dif)-LSD	maleProf	maleColl	maleHS	femaleHS	femaleColl	femaleProf
maleProf	-1.67	-1.13	1.38	3.00	3.62	4.15
maleColl	-1.13	-1.67	0.84	2.46	3.08	3.61
maleHS	1.38	0.84	-1.67	-0.05	0.57	1.10

femaleHS	3.00	2.46	-0.05	-1.67	-1.05	-0.52
femaleColl	3.62	3.08	0.57	-1.05	-1.67	-1.14
femaleProf	4.15	3.61	1.10	-0.52	-1.14	-1.67

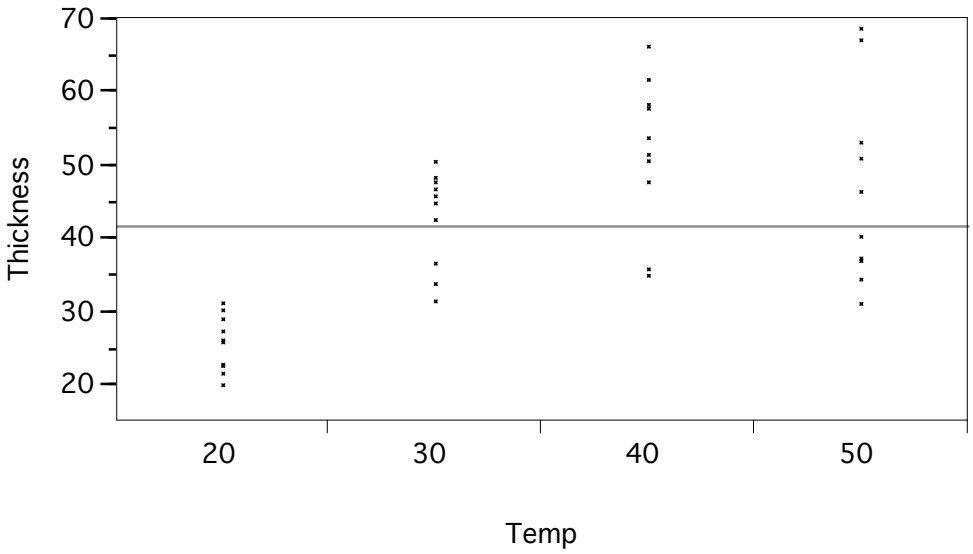
Positive values show pairs of means that are significantly different.

(39) Is there a statistically significant difference among these six groups in how, on average, they evaluate the new razor?
(a) No, the group means are too close relative to the background random variation.
(b) No, there is significant interaction between *Sex* and *Education.*
(c) Yes, the two-way anova indicates significant differences for *Sex* and *Education*.
(d) Yes, the Tukey-Kramer procedure indicates significant differences.
(e) This question cannot be answered without the parameter estimates from the anova.

(40) From the shown output, we can conclude that
(a) Better educated customers prefer the new razor significantly more than others.
(b) Better educated, male customers prefer the new razor significantly more than others.
(c) Male customers in all groups rate the product significantly higher than female customers.
(d) Female customers are significantly more well-educated than male customers on average.
(e) A larger sample of customers is needed to find significant differences.

(41) Does the level of education as measured here (high school, college, professional) impact the ratings offered by men and by women in the same way?
(a) No, because there is too much collinearity in this problem.
(b) No, since the p-value for *Education* is only 0.03.
(c) Yes, because the multiple comparisons indicate similar group means.
(d) No, because of the significant interaction.
(e) Yes, because the F-statistic for *Sex* is significant.

(Questions 42-46) A company has developed a novel process for depositing an insulating film over certain critical components used in computer systems. The insulating film is useful since it allows components to be located closer on a circuit board without interference, thus allowing a smaller overall system package. As part of its study of this novel process, the company ran a series of tests of the process at several temperatures, obtaining 10 measurements at each of four temperatures: 20, 30, 40 and 50, in degrees Centigrade. The tests measured the effect of the temperature in the reaction chamber on the amount of insulation that was deposited. Thick deposits are good deposits.



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Temp	3	3855.24	1285.08	15.1823	<.0001
Error	36	3047.15	84.64		
C. Total	39	6902.39			

Means

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
20	10	25.48	2.91	19.58	31.38
30	10	42.66	2.91	36.76	48.56
40	10	51.64	2.91	45.74	57.54
50	10	46.46	2.91	40.56	52.36

Std Error uses a pooled estimate of error variance

Differences between Means

Dif=Mean[i]-Mean[j]	40	50	30	20
40	0.0000	5.1870	8.9847	26.1665
50	-5.1870	0.0000	3.7977	20.9795
30	-8.9847	-3.7977	0.0000	17.1819
20	-26.1665	-20.9795	-17.1819	0.0000

Comparisons for each pair using Student's t

Abs(Dif)-LSD	40	50	30	20
40	-8.34	-3.16	0.64	17.82
50	-3.16	-8.34	-4.55	12.64
30	0.64	-4.55	-8.34	8.84
20	17.82	12.64	8.84	-8.34

Positive values show pairs of means that are significantly different.

Comparisons for all pairs using Tukey-Kramer HSD

Abs(Dif)-LSD	40	50	30	20
40	-11.08	-5.89	-2.10	15.09
50	-5.89	-11.08	-7.28	9.90
30	-2.10	-7.28	-11.08	6.10
20	15.09	9.90	6.10	-11.08

Positive values show pairs of means that are significantly different.

Comparisons with the best using Hsu's MCB

Mean[i]-Mean[j]-LSD	40	50	30	20
40	-8.78	-3.59	0.21	17.39
50	-13.96	-8.78	-4.98	12.20
30	-17.76	-12.57	-8.78	8.41
20	-34.94	-29.75	-25.96	-8.78

If a column has any positive values, the mean is significantly less than the max.

Mean[i]-Mean[j]+LSD	40	50	30	20
40	8.78	13.96	17.76	34.94
50	3.59	8.78	12.57	29.75
30	-0.21	4.98	8.78	25.96
20	-17.39	-12.20	-8.41	8.78

If a column has any negative values, the mean is significantly greater than the min.

(42) These results indicate that the thickest deposits occur
- (a) At 40 degrees, significantly higher than at any other temperatures.
- (b) At 40 degrees, but the average deposit at 50 is not signficantly less.
- (c) From 30 to 50 degrees, with those at 20 degrees being significantly less.
- (d) Throughout this range of temperatures.
- (e) At temperatures outside this range.

(43) The company has been planning to fabricate a large facility to implement this process using a design that features relatively cool 30 degree reaction chamber. Do the results shown above suggest a reason to change this design?
- (a) No, the deposits at 30 degrees are not significantly different from those at 40 degrees.
- (b) No, the results are not significantly different over this range of temperatures.
- (c) Yes, the deposits at 30 degrees are significantly lower than those at 40 degrees.
- (d) Yes, the deposits at 20 degrees are significantly lower than those at other temperatures.
- (e) Yes, the deposits at 50 degrees are significantly lower than those at 40 degrees.

(44) From the overall F statistic given in the Anova summary table, we can conclude that
- (a) There are no differences among the group mean values.
- (b) There are significant differences among the group means.
- (c) The variances are different in the groups.
- (d) The variances are comparable in the groups.

(e) The mean deposit obtained at 40 degrees is significantly higher than at other temperatures.

(45) A consultant has informed this company that the above results are inappropriate and that the company should use a regression model with temperature as a "continuous" predictor in a quadratic regression (i.e., a polynomial regression with temperature and temperature squared). If the company takes this advice, then the largest possible value for the R^2 of the quadratic model
(a) Will be about 0.35.
(b) Will be about 0.45
(c) Will be about 0.55
(d) Will be about 0.65
(e) Cannot be determined from the available output.

(46) The company is using these results to predict the thickness of the coating when deposited at 30 degrees. From the shown analysis, when predicting the thickness of a *single* deposit at 30 degrees, the actual prediction error produced by this model
(a) Will be about ± 18.
(b) Will be about ± 5.8.
(c) Will be about ± 2 RMSE of the fitted model.
(d) Will be less than ± 2 RMSE of the fitted model.
(e) Cannot be ascertained without an accompanying nonlinear regression model.