IE 361 Exam 1
Fall 2006

I have neither given nor received unauthorized assistance on this exam.

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Name Date

This exam consists of 20 multiple choice questions. There is a single best answer for each question. **Circle EXACTLY ONE response** for each question on this answer sheet.

1.	**A**	**B**	**C**	**D**	**E**
2.	**A**	**B**	**C**	**D**	**E**
3.	**A**	**B**	**C**	**D**	**E**
4.	**A**	**B**	**C**	**D**	**E**
5.	**A**	**B**	**C**	**D**	**E**
6.	**A**	**B**	**C**	**D**	**E**
7.	**A**	**B**	**C**	**D**	**E**
8.	**A**	**B**	**C**	**D**	**E**
9.	**A**	**B**	**C**	**D**	**E**
10.	**A**	**B**	**C**	**D**	**E**
11.	**A**	**B**	**C**	**D**	**E**
12.	**A**	**B**	**C**	**D**	**E**
13.	**A**	**B**	**C**	**D**	**E**
14.	**A**	**B**	**C**	**D**	**E**
15.	**A**	**B**	**C**	**D**	**E**
16.	**A**	**B**	**C**	**D**	**E**
17.	**A**	**B**	**C**	**D**	**E**
18.	**A**	**B**	**C**	**D**	**E**
19.	**A**	**B**	**C**	**D**	**E**
20.	**A**	**B**	**C**	**D**	**E**

1. Rationale behind the "process orientation" of modern quality assurance
a) presumes that good processes produce good outcomes.
b) presumes that reworking items on a production line is an efficient way to achieve high quality.
c) focuses on the use of robots as replacements for error-prone human beings.
d) Exactly 2 of responses a) through c) are correct completions of the sentence.
e) None of responses a) through c) are correct completions of the sentence.

2. "Quality" and "statistics" are related because
a) guaranteeing quality requires gathering data and taking actions based on data.
b) both quality and statistics are exclusively quantitative subjects.
c) both quality and statistics are concerned in some way with "variation."
d) Exactly 2 of responses a) through c) are correct completions of the sentence.
e) All of responses a) through c) are correct completions of the sentence.

3. Regarding simple statistical graphics and quality assurance applications,
a) histograms are basically "static" tools, giving a snapshot of process performance, but no sense of how process output has evolved.
b) run charts portray process behavior over time.
c) marking specifications on a graphic like a histogram or run chart allows one to get a quick sense of "process capability."
d) None of responses a) through c) are correct completions of the sentence.
e) All of responses a) through c) are correct completions of the sentence.

4. If a measurement device is perfectly calibrated
a) it returns measurements of a measurand that are free of error.
b) it has no bias of measurement.
c) it has negligible imprecision.
d) it fails to be "linear."
e) None of responses a) through d) are correct completions of the sentence.

5. A standard (an item with corresponding "known" measurand x)
a) is needed in both measurement device calibration and determination of σ_{device}.
b) is needed in measurement device calibration, but not in determination of σ_{device}.
c) is not needed in measurement device calibration, but is needed in determination of σ_{device}.
d) is not needed for either device calibration or for determination of σ_{device}.

6. A measurement device may have a bias as large as 1 unit (in absolute value) and a device standard deviation as large as 1 unit. You measure x and observe $y = 10$. If you believe in the simple (normal) measurement model and want to report an interval you are "at least 99% sure" contains x, you should report limits
a) 10 ± 1.
b) 10 ± 2.
c) 10 ± 3.
d) 10 ± 4.
e) None of the limits a) through d) is adequate.
(Hint for **6**: Before measurement, how far do you expect y to be from x with the indicated worst possible values of absolute bias and standard deviation?)

Fact: The upper 2.5% point of the $F_{24,24}$ distribution is about 2.27.

7. The same axel diameter is measured $n_1 = 25$ times on device #1 and $n_2 = 25$ times on device #2, with resulting means and standard deviations $\bar{y}_1 = 2.001 \text{ in}$, $\bar{y}_2 = 2.004 \text{ in}$, $s_1 = .003 \text{ in}$, and $s_2 = .004 \text{ in}$. Based on 95% confidence limits, one can conclude

a) that there is no clear difference in either device biases or standard deviations.
b) that there is no clear difference in device biases, but there is a clear difference in device standard deviations.
c) that there is a clear difference in device biases, but no clear difference in device standard deviations.
d) that there are clear differences in both device biases and in device standard deviations.
e) nothing about comparison of device biases or standard deviations since the true axel diameter is not known.

8. Two different (physically stable) production lines produce plastic pop bottles. $n_1 = 25$ bottles from line #1 and $n_2 = 25$ bottles from line #2 are burst tested on a single tester, with resulting means and standard deviations $\bar{y}_1 = 201 \text{ psi}$, $\bar{y}_2 = 202 \text{ psi}$, $s_1 = 3 \text{ psi}$, and $s_2 = 4 \text{ psi}$. Based on 95% confidence limits, one can conclude

a) that there is no clear difference between mean burst strengths or consistencies of burst strengths produced on the two lines.
b) that there is no clear difference between mean burst strengths, but there is a clear difference between consistencies of burst strengths on the two lines.
c) that there is a clear difference between mean burst strengths, but no clear difference between consistencies of burst strengths produced on the two lines.
d) that there is a clear difference between both mean burst strengths and between consistencies of burst strengths produced on the two lines.
e) nothing about comparison of line mean burst strengths or consistencies of burst strengths since measurement is destructive and bottles can not be retested.

(For questions 9 and 10) Using a single tester, a single metal specimen is tested for Brinell hardness 20 times, with resulting sample standard deviation of hardness 10 HB. Subsequently, 40 different specimens cut from the same ingot of steel have sample standard deviation of measured hardness 20 HB on this tester.

9. 95% confidence limits for a standard deviation measuring "test variability" for this tester

a) are 16 HB to 26 HB.
b) are 13 HB to 33 HB.
c) are 8 HB to 15 HB.
d) are 6 HB to 21 HB.
e) can not be determined from the given information.

10. Approximate 95% confidence limits for a specimen-to-specimen standard deviation of actual Brinell hardness

a) can not be determined from the given information.
b) are 8 HB to 15 HB.
c) are 16 HB to 26 HB.
d) are 13 HB to 25 HB.
e) None of responses a) through d) are a correct completion of the sentence.

11. Below is part of a `JMP` report from the analysis of a very small Gauge R&R study involving only $I = 1$ part and $J = 2$ operators. (The data are actually the "8D4 Ring Gear Height" data from problem 2.7 of *SQAME*.) Units used entering the data were 10^{-5} inch above 1.88000 inch .

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Operator	1.3555321	1602.9167	2547.1098	-3389.419	6595.2519	57.547
Residual		1182.5	528.83008	577.30301	3641.8538	42.453
Total		2785.4167				100.000

In these units, 95% confidence limits for the reproducibility standard deviation

a) are not available based on the given information.

b) are 0 in to 6595×10^{-5} in .

c) are 557×10^{-5} in to 3642×10^{-5} in .

d) are 0 in to 81×10^{-5} in .

e) are 24×10^{-5} in to 60×10^{-5} in .

Below is part of a `JMP` report from the analysis of an only slightly larger Gauge R&R study involving only $I = 2$ part**s** and $J = 2$ operators**.** (The data are actually the "8D4 and 31D4 Ring Gear Height" data from problem 2.7 of *SQAME*.) Units used entering the data were again 10^{-5} inch above 1.88000 inch . Use this `JMP` report in answering questions **12** and **13**.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	239512.50	79837.5	64.0408
Error	20	24933.33	1246.7	Prob > F
C. Total	23	264445.83		<.0001*

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Part	1	1	218504.17	175.2707	<.0001*
Operator	1	1	21004.17	16.8483	0.0006*
Part*Operator	1	1	4.17	0.0033	0.9545

12. Based on this second report, 95% confidence limits for the repeatability standard deviation

a) are impossible to determine.

b) are 27×10^{-5} in to 51×10^{-5} in .

c) are 995×10^{-5} in to 1800×10^{-5} in .

d) are 65×10^{-5} in to 4583×10^{-5} in .

e) are 160×10^{-5} in to 1053×10^{-5} in .

13. Based on this second report, a single number estimate of $\sigma_{\text{reproducibility}}$

a) is 1247×10^{-5} in .

b) is 35×10^{-5} in .

c) is 1534×10^{-5} in .

d) is 39×10^{-5} in .

e) can not be determined.

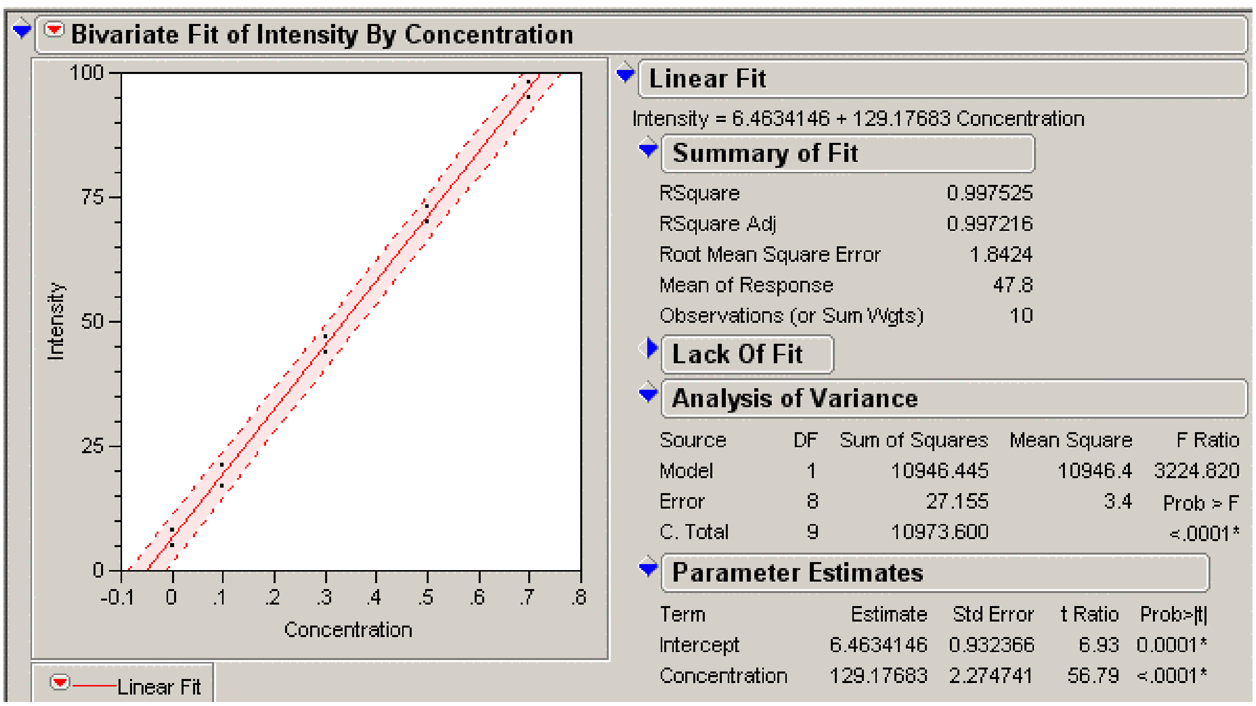
14. An ANOVA analysis of a Gauge R&R data set produces $\hat{\sigma}_{\text{R\&R}} = 53$ (in appropriate units) and $\hat{\nu}_{\text{R\&R}} = 3$. In these units, engineering specifications on a critical dimension of a machined steel part are *nominal* ± 200. Approximate 95% confidence limits for a GCR (gauge capability ratio) for checking conformance to these specification are

a) impossible to determine.
b) .1 to .9 .
c) .5 to 3.0 .
d) .8 to 1.6 .
e) 1.0 to 6.0 .

15. 95% confidence limits for a particular gauge capability ratio are .6 to .8 . This indicates

a) that the gauge is inadequate for checking conformance to the specifications in question.
b) that the gauge is adequate for checking conformance to the specifications in question.
c) more data are needed to determine whether the gauge is adequate for checking conformance to the specifications in question.
d) there are clearly problems with the accuracy of the gauge.
e) Exactly 2 of the responses a) through d) are correct completions of the sentence.

Below is part of a `JMP` report from the analysis of a calibration data set. Use it in answering questions **16** and **17**. The data are from an analyzer that returns light intensities y (in unspecified units) for specimens of Riboflavin concentration x (in mcg/mL).



Linear Fit

Intensity = 6.4634146 + 129.17683 Concentration

Summary of Fit

RSquare	0.997525
RSquare Adj	0.997216
Root Mean Square Error	1.8424
Mean of Response	47.8
Observations (or Sum Wgts)	10

Lack Of Fit

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	10946.445	10946.4	3224.820
Error	8	27.155	3.4	Prob > F
C. Total	9	10973.600		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	6.4634146	0.932366	6.93	0.0001*
Concentration	129.17683	2.274741	56.79	<.0001*

16. 95% confidence limits for a repeatability standard deviation for this analyzer are

a) .6 to 1.8 intensity units .
b) 1.2 to 3.5 intensity units .
c) 1.5 to 4.4 intensity units .
d) 2.3 to 6.5 intensity units .
e) impossible to determine from the given information.

17. Tomorrow this analyzer is used on an unknown specimen and $y = 75$ intensity units is read on the display of the analyzer. 95% confidence limits for the Riboflavin concentration of the sample

a) can not be determined from the information provided.
b) are .50 to .57 mcg/mL .
c) are .52 to .55 mcg/mL .
d) are 4.3 to 8.6 mcg/mL .
e) are 123.9 to 134.4 mcg/mL .

The final step in the production of some glass vials is a visual inspection presently carried out by human inspectors. A particular single vial (marked in an "invisible" ink that can be seen only under ultraviolet light) known to be defective is repeatedly run through the inspection process among a large number of newly produced vials. In fact, each of 5 company inspectors sees that vial 10 times in a company study. Below are the rates at which that vial was identified as defective by the operators

$$.6,.9,.9,1.0,1.0$$

18. Inconsistency of the "defective/non-defective" calls made by a particular single inspector

a) is a kind of "repeatability" variation.
b) is modeled using a binomial distribution.
c) is reflected in values of $\hat{p}$ that are neither 0 nor 1.
d) Exactly 2 of responses a) through c) are correct completions of the sentence.
e) All of responses a) through c) are correct completions of the sentence.

19. On the scale of (estimated) variances (not standard deviations) the fraction of overall variation seen in the "defective/non-defective" calls that should be attributed to operator-to-operator differences is closest to

a) 0
b) .1
c) .2
d) .3
e) .4

20. A comparison between one of the operators that made all "defective" calls and the one that made 6 out of 10 such calls can be made using approximate 95% confidence limits (for the difference in long run fractions of "defective" calls)

a) $.4 \pm 1.96(.04)$
b) $.4 \pm 1.96(.15)$
c) $.4 \pm 1.96(.19)$
d) $.29 \pm 1.96(.04)$
e) $.29 \pm 1.96(.19)$

IE 361 Exam 2
Fall 2006

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Name   Date

This exam consists of 20 multiple choice questions. There is a single best answer for each question. **Circle EXACTLY ONE response** for each question on this answer sheet.

1.	**A**	**B**	**C**	**D**	**E**
2.	**A**	**B**	**C**	**D**	**E**
3.	**A**	**B**	**C**	**D**	**E**
4.	**A**	**B**	**C**	**D**	**E**
5.	**A**	**B**	**C**	**D**	**E**
6.	**A**	**B**	**C**	**D**	**E**
7.	**A**	**B**	**C**	**D**	**E**
8.	**A**	**B**	**C**	**D**	**E**
9.	**A**	**B**	**C**	**D**	**E**
10.	**A**	**B**	**C**	**D**	**E**
11.	**A**	**B**	**C**	**D**	**E**
12.	**A**	**B**	**C**	**D**	**E**
13.	**A**	**B**	**C**	**D**	**E**
14.	**A**	**B**	**C**	**D**	**E**
15.	**A**	**B**	**C**	**D**	**E**
16.	**A**	**B**	**C**	**D**	**E**
17.	**A**	**B**	**C**	**D**	**E**
18.	**A**	**B**	**C**	**D**	**E**
19.	**A**	**B**	**C**	**D**	**E**
20.	**A**	**B**	**C**	**D**	**E**

1. The purpose of control charting is to
  a) detect process change.
  b) detect substandard process outcomes/output.
  c) separate special cause variation from common cause variation.
  d) All of responses a) through c) are correct completions of the sentence.
  e) Exactly 2 of responses a) through c) are correct completions of the sentence.

2. Unadjusted, a particular lathe used to cut rings in plastic cylinders is actually physically stable (and could be seen to be so by control charting individuals or mean ring diameters). But instead of doing control charting, an operator measures each ring diameter as it is made and adjusts the tool for cutting the next ring according to how the current one measures. (For example, if the current diameter is $.001$ in bigger than the target diameter, the tool is adjusted to cut an extra $.001$ inch off the diameter of the next one produced.) These adjustments
  a) will have no effect on consistency of ring diameters (over leaving the machine alone).
  b) are likely to improve the consistency of ring diameters (over leaving the machine alone).
  c) are likely to degrade the consistency of ring diameters (over leaving the machine alone).
  d) may affect consistency of ring diameters (over leaving the machine alone) but the nature of any such change is unpredictable.

3. Retrospective control charts
  a) are of more practical importance than standards given control charts.
  b) are based on a provisional assumption of process stability and estimation of process parameters.
  c) Both of a) and b) are correct completions of the sentence.
  d) Neither of a) and b) are correct completions of the sentence.

Below are sample means and standard deviations from 10 samples of size $n = 4$. Use the information from these samples to answer questions 4 through 6.

Sample	1	2	3	4	5	6	7	8	9	10	Sum
$\bar{x}$	7.0	7.9	7.1	7.7	5.2	5.4	6.4	6.5	5.8	6.8	65.8
s	1.5	3.1	3.4	1.1	1.4	1.0	2.5	0.7	1.4	1.1	17.2

4. Consider standards given control charting for both $\bar{x}$ and s, with standards $\mu = 6.0$ and $\sigma = 1.5$.
  a) The $\bar{x}$ chart and s chart both produce out-of-control signals.
  b) The $\bar{x}$ chart produces out-of-control signals, but the s chart does not.
  c) The $\bar{x}$ chart produces no out-of-control signals, but the s chart produces signals.
  d) Neither chart produces out-of-control signals.

5. Consider retrospective control charting for both $\bar{x}$ and s.
  a) The $\bar{x}$ chart and s chart both produce out-of-control signals.
  b) The $\bar{x}$ chart produces out-of-control signals, but the s chart does not.
  c) The $\bar{x}$ chart produces no out-of-control signals, but the s chart produces signals.
  d) Neither chart produces out-of-control signals.

6. Ignore any lack of stability that you found in the sample standard deviations on the previous page and use the values there to estimate σ. Based on this estimate, in turn estimate the mean of a range (μ_R) for an additional sample of size $n = 6$. (Remember that the samples represented in the table were of size $n = 4$.) This estimate is closest to

a) 1.87
b) 3.54
c) 3.84
d) 4.36
e) 4.73

7. Below are 3 statements about control charting. How many of them are true?

- Median charting is less sensitive to process change than $\bar{x}$ charting.
- Control charting is a process improvement technique only to the extent that it helps bring process performance to the best level possible given its current configuration.
- Process stability has no direct connection to product acceptability.

a) All 3 are correct.
b) Exactly 2 are correct.
c) Exactly 1 is correct.
d) None are correct.

8. A particular visual inspection method historically has only a 40% rate of correctly identifying nonconforming items. After some operator training, marked items known to be defective are mixed with current production (100 known defectives per shift) and sent through an inspection station. Standards given control limits for fractions of the defective items correctly identified on a given shift

a) are .25 and .55.
b) are .21 and .59.
c) allow for detection of improved inspection performance when a sample detection rate is above the upper control limit.
d) Both a) and c) are correct completions of the sentence.
e) Both b) and c) are correct completions of the sentence.

9. Below are some records from inspection for paint defects on a model of large machine.

Machine	1	2	3	4	5	6	7	8	9	10	Sum
Defects	9	5	4	4	7	2	6	3	5	5	50

These data

a) show no evidence of painting process instability when looked at retrospectively.
b) provide clear evidence of a process improvement if a rate of 10 defects per machine has been "standard."
c) are an example of "measurement" or "variables" data.
d) Exactly 2 of a) through c) are correct completions of the sentence.
e) All of a) through c) are correct completions of the sentence.

10. A positive lower control limit on a range chart

a) allows the possibility of detecting unexpected "good" assignable causes.
b) is available only for sample sizes of at least 7.
c) means that for process parameters μ and σ (for basic observations), it must be the case that $\mu - 3\sigma > 0$.
d) Exactly 2 of a) through c) are correct completions of the sentence.
e) All of a) through c) are correct completions of the sentence.

11. "Patterns" visible on a control chart

a) suggest the presence of assignable cause variation even when no points reach control limits.
b) can give hints regarding their physical source.
c) motivate the creation of sets of "extra alarm rules" like the Western Electric Rules.
d) Exactly 2 of a) through c) are correct completions of the sentence.
e) All of a) through c) are correct completions of the sentence.

12. Using sets of "extra alarms rules" like the Western Electric Rules

a) produces no effect on the "false alarm frequency" for a Shewhart $\bar{x}$ chart (compared to that of the single "one point outside 3-sigma limits" rule).
b) reduces the "false alarm frequency" for a Shewhart $\bar{x}$ chart (below that of the single "one point outside 3-sigma limits" rule).
c) increases the "false alarm frequency" for a Shewhart $\bar{x}$ chart (over that of the single "one point outside 3-sigma limits" rule).
d) affects the "false alarm frequency" for a Shewhart $\bar{x}$ chart (relative to that of a single "one point outside 3-sigma limits" rule), but the nature of that effect can not be predicted.

13. Process standards are $\mu = 100$ and $\sigma = 7$ and observations from the process are normally distributed. Below are 3 statements about Shewhart $\bar{x}$ charts for this process. How many of them are true?

- Charts for $n = 5$ and $n = 10$ have the same control limits.
- Charts for $n = 5$ and $n = 10$ have the same ARL if process parameters remain at standard values.
- Charts for $n = 5$ and $n = 10$ have the same ARL if the process mean changes from the standard value.

a) All 3 are correct.
b) Exactly 2 are correct.
c) Exactly 1 is correct.
d) None are correct.

14. If process standards for a normally distributed variable are $\mu = 100$ and $\sigma = 7$ and specifications on the variable are 100 ± 10, based on samples of size $n = 4$

a) it is impossible to use a Shewhart p chart to do process monitoring.
b) it is possible to use a Shewhart p chart to do process monitoring, with the standard value of $p = .0027$.
c) it is possible to use a Shewhart p chart to do process monitoring, with a standard value of $p = .0042$.
d) it is possible to use a Shewhart p chart to do process monitoring with a standard value of $p = .1528$.
e) it is possible to use a Shewhart p chart to do process monitoring with a standard value of $p = .2420$.

15. In comparing two methods of control charting, Method A is clearly preferable to Method B relative to "All OK" and some "not All OK" process condition if

a) $ARL_{\mathrm{A}} > ARL_{\mathrm{B}}$ when "All is OK" and $ARL_{\mathrm{A}} > ARL_{\mathrm{B}}$ when "All is not OK."
b) $ARL_{\mathrm{A}} > ARL_{\mathrm{B}}$ when "All is OK" and $ARL_{\mathrm{A}} < ARL_{\mathrm{B}}$ when "All is not OK."
c) $ARL_{\mathrm{A}} < ARL_{\mathrm{B}}$ when "All is OK" and $ARL_{\mathrm{A}} > ARL_{\mathrm{B}}$ when "All is not OK."
d) $ARL_{\mathrm{A}} < ARL_{\mathrm{B}}$ when "All is OK" and $ARL_{\mathrm{A}} < ARL_{\mathrm{B}}$ when "All is not OK."

16. 10 consecutive samples of size $n = 1$ from a process are as below

Sample	1	2	3	4	5	6	7	8	9	10	Mean
x	1.01	2.03	.98	1.97	.95	1.97	.97	2.07	.96	1.97	1.488
MR		1.02	1.05	.99	1.02	1.02	1.00	1.10	1.11	1.01	1.0356

Further,

$$1.0356/1.128 = .918$$

a) A retrospective individuals chart based on the best available estimate of σ indicates there is process instability, and this analysis appears to be appropriate.
b) A retrospective individuals chart based on the best available estimate of σ indicates no process instability, and this analysis appears to be appropriate.
c) A retrospective individuals chart based on the best available estimate of σ indicates there is process instability, but the very regular and relatively large cycles in the data make it clear that this estimate and analysis are inappropriate.
d) A retrospective individuals chart based on the best available estimate of σ indicates no process instability, but the very regular and relatively large cycles in the data make it clear that this estimate and analysis are inappropriate.

17. Below are 3 statements about normal plots (normal quantile plots in `JMP` language). How many of them are true?

- "Near linearity" on such a plot means that the process generating the data was in control during data collection.
- When the plot is reasonably linear, its slope is closely related to data set variability.
- When most of a normal plot is reasonably linear but the lower left point on the plot looks as if it is "pulled left" away from the line established by the rest of the points, there is indication that a normal model would understate the fraction of "small" values produced by a stable process leading to the data set.

a) All 3 of the statements are true.
b) Exactly 2 of the statements are true.
c) Exactly 1 of the statements is true.
d) None of the statements is true.

Data from problem 5.8 of *SQAME* are measured hardness values from $n = 8$ heat-treated steel parts produced on a single day. These have $\bar{x} = 3.150$ mm, $s = .0443$ mm, $\min x_i = 3.100$ mm, and $\max x_i = 3.200$ mm. We'll assume that specifications on this hardness are $3.100 \pm .150$ mm. Use these facts to answer questions 18 through 20.

18. Assuming hardness to be normally distributed, what are limits you are "95% sure" would bracket one more (a 9^{th}) part hardness value?

a) 3.100 mm and 3.200 mm
b) $3.150 \pm .036$ mm
c) $3.150 \pm .037$ mm
d) $3.150 \pm .108$ mm
e) $3.150 \pm .111$ mm

19. Again assuming hardness to be normally distributed, 95% confidence limits for a capability ratio measuring current process performance (as opposed to process potential)

a) are .18 mm and .54 mm.
b) are .55 and 1.71.
c) are .30 and 1.21.
d) None of the above are close to correct.

20. Again assuming hardness to be normally distributed, 95% confidence limits for a capability ratio measuring process potential (as opposed to current process performance)

a) are .18 mm and .54 mm.
b) are .55 and 1.71.
c) are .30 and 1.21.
d) None of the above are close to correct.

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8.	**A**	**B**	**C**	**D**	**E**
9.	**A**	**B**	**C**	**D**	**E**
10.	**A**	**B**	**C**	**D**	**E**
11.	**A**	**B**	**C**	**D**	**E**
12.	**A**	**B**	**C**	**D**	**E**
13.	**A**	**B**	**C**	**D**	**E**
14.	**A**	**B**	**C**	**D**	**E**
15.	**A**	**B**	**C**	**D**	**E**
16.	**A**	**B**	**C**	**D**	**E**
17.	**A**	**B**	**C**	**D**	**E**
18.	**A**	**B**	**C**	**D**	**E**
19.	**A**	**B**	**C**	**D**	**E**
20.	**A**	**B**	**C**	**D**	**E**

1. The force opposing the motion of a block of weight W moving across a flat horizontal surface is

$$F = kW$$

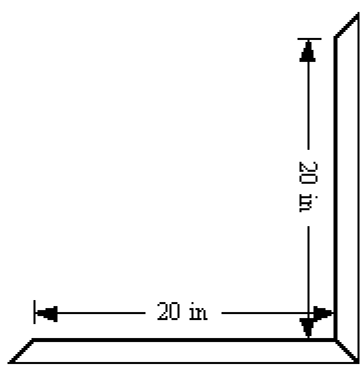
for k a coefficient of kinetic friction specific to the block and the surface. Suppose that in an application of this simple physical relationship, W is variable with mean $\mu_W = 10$ lbs and standard deviation $\sigma_W = .2$ lb, and that k varies independently with mean $\mu_k = .3$ and standard deviation $\sigma_k = .01$. An approximation for the standard deviation of the force require to accelerate the block

- **a)** is .014 lb
- **b)** is .041 lb
- **c)** is .12 lb
- **d)** is .21 lb
- **e)** cannot be determined from the given information.

2. Sheets of book paper have mean thickness .01 in and standard deviation .0001 in. A particular book will have 200 sheets of this paper in it. Copies of the book will have (exclusive of the cover) mean thickness 2.00 in. I should expect about 95% of copies to have thickness within how much of this mean?

- **a)** .0002 in
- **b)** .0014 in
- **c)** .0028 in
- **d)** .0400 in

3. All 4 wooden sides of a certain window manufactured by Producer X are designed to be 20 inches from inside corner to inside corner as shown in the schematic below. Suppose that upon assembling two legs of the window frame as shown in the figure, the inside diagonal is measured. (We'll assume that these parts can be assembled to produce a square corner and we'll ignore measurement error for our present purposes.) An assembly is "good" only when the diagonal is $28.28 \pm .05$ in and manufacturing variation produces not exactly 20 inch parts, but rather legs with mean indicated dimension $\mu = 20$ in and standard deviation of the dimension $\sigma = .04$ in .



So called "statistical tolerancing" methods

- **a)** can be used to find an approximate mean and standard deviation for diagonals and (then assuming a normal distribution) predict the fraction of assemblies failing to meet specifications on the diagonal measurement.
- **b)** are based on a probability model assumes independence of the horizontal and vertical measurements.
- **c)** here depend upon knowing the Pythagorean theorem.
- **d)** All of **a)** through **c)** are correct completions of the sentence.
- **e)** Exactly two of **a)** through **c)** are correct completions of the sentence.

An ISU engineering statistics student project concerned

$$y = \text{glued wood joint strength (lb)}$$

for several wood types and glues. Below are some summary statistics for oak wood and three types of glue. Use this information in questions **4.** and **5.** below.

white glue	**carpenter's glue**	**cascamite glue**
$n_1 = 3$	$n_2 = 3$	$n_3 = 3$
$\bar{y}_1 = 257.7$ lb	$\bar{y}_2 = 234.3$ lb	$\bar{y}_3 = 177.7$ lb
$s_1 = 5.7$ lb	$s_2 = 3.2$ lb	$s_3 = 10.1$ lb

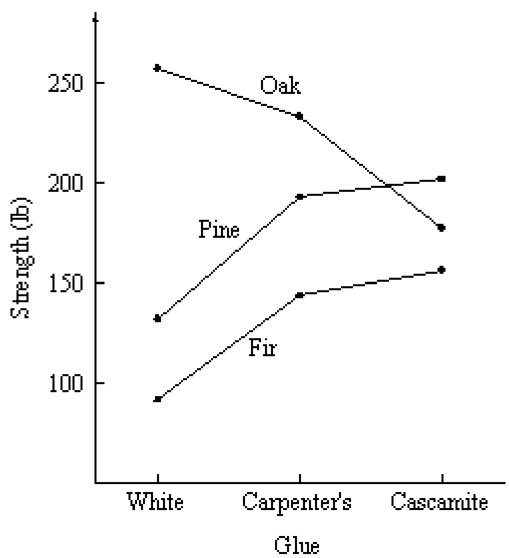
4. An estimate of the standard deviation of joint strength for oak wood and any one of the three glue types useful for making confidence limits for linear combinations of means

- **a)** is 6.3 with 9 degrees of freedom.
- **b)** is 6.3 with 6 degrees of freedom.
- **c)** is 6.9 with 9 degrees of freedom.
- **d)** is 6.9 with 6 degrees of freedom.

5. Two-sided confidence limits for $\frac{1}{2}(\mu_1 + \mu_2) - \mu_3$ provide a kind of comparison of cascamite to the other two glues and are of the form

- **a)** $68.3 \pm t \cdot s_{\text{pooled}}(.58)$
- **b)** $68.3 \pm t \cdot s_{\text{pooled}}(.71)$
- **c)** $68.3 \pm t \cdot s_{\text{pooled}}(.82)$
- **d)** $68.3 \pm t \cdot s_{\text{pooled}}(1.00)$
- **e)** None of **a)** through **d)** is close to correct.

Actually, the original joint strength study was a 3×3 factorial study with constant sample size $m = 3$ and $s_{\text{pooled}} = 8.0$ lbs. Below is an interaction plot from the whole study.



Use this information in answering questions **6.** through **10.**

6. By the standard of two-sided 95% confidence limits, each mean plotted on the interaction plot is "good to within" about

- **a)** 3.2 lb
- **b)** 4.2 lb
- **c)** 6.5 lb
- **d)** 9.7 lb
- **e)** 16.8 lb

7. Pine and fir are "soft" woods and oak is a "hardwood." The interaction plot suggests

- **a)** that soft and hard woods react fundamentally differently to changes in glue type.
- **b)** that soft woods have a single pattern of reaction to changes in glue type.
- **c)** that there are consistent differences in joint strength between different soft woods.
- **d)** All of **a)**, **b)** and **c)** are correct completions of the sentence.
- **e)** Exactly two of **a)**, **b)** and **c)** are correct completions of the sentence.

8. The interaction plot suggests that

- **a)** there are no interactions between wood type and glue type and there is no difference between pine and fir main effects.
- **b)** there are no interactions between wood type and glue type but there is a difference between pine and fir main effects.
- **c)** there are interactions between wood type and glue type but there is no difference between pine and fir main effects.
- **d)** there are both interactions between wood type and glue type and a difference between pine and fir main effects.

9. The difference in pine and fir average (across glues) sample means is 43.6 lb. Thus, by the standard of two-sided 95% confidence limits, the difference in pine and fir main effects

- **a)** is 43.6 ± 3.7 lb
- **b)** is 43.6 ± 4.0 lb
- **c)** is 43.6 ± 4.6 lb
- **d)** is 43.6 ± 6.5 lb
- **e)** is 43.6 ± 7.9 lb

10. The sample mean strength for white glue joints on oak wood is 257.7 lb. The average (across glues) of oak sample mean strengths is 223.2 lb. The average (across woods) of white glue mean strengths is 160.5 lb. The average of all nine sample mean strengths is 176.7 lb. The fitted interaction between oak wood and white glue

- **a)** is -16.2
- **b)** is 46.5
- **c)** is 50.7
- **d)** cannot be computed from the information provided.
- **e)** is none of the values in **a)**, **b)** or **c)**, but can be computed from the information provided.

In a balanced 2^3 complete factorial machining experiment with response variable

$y =$ a suface finish measurement on a particular 1 inch section of the machined part (this is a measure of the vertical distance a probe moves up and down as it is dragged across the part … large values indicate a rough surface), factors and their levels were

Factor	"low"		"high"
A- Speed	2500 rpm	vs	4500 rpm
B- Feed	.003 in/rev	vs	.009 in/rev
C- Tool Condition	New	vs	Used (after 250 parts)

The common sample size was $m = 2$ and s_{pooled} was 7.5. The Yates algorithm produced fitted effects

$$\bar{y}_{...} = 131.9, a_2 = 5.0, b_2 = 92.4, ab_{22} = -.3,$$
$$c_2 = -3.8, ac_{22} = -2.9, bc_{22} = -4.0, abc_{222} = -1.9$$

Use this information in answering questions **11.** through **15.**

11. There were eight different combinations of levels of factors in this study, each with a sample mean, $\bar{y}$. The average of those sample means for Used tools minus the average of sample means for New tools

- **a)** is -3.8.
- **b)** is -7.6.
- **c)** measures interaction of factor C with the other two factors.
- **d)** Both **a)** and **c)** are correct completions of the sentence.
- **e)** Both **b)** and **c)** are correct completions of the sentence.

12. 95% two-sided confidence limits for the standard deviation of y for any fixed combination of levels of Factors A,B, and C

- **a)** are 1.8 and 5.2
- **b)** are 4.0 and 11.6
- **c)** are 5.1 and 14.4
- **d)** cannot be determined from the given information.
- **e)** are not given in any of **a)**, **b)**, or **c)**, but can be determined from the information provided.

13. The "margin of error" for any of the fitted effects listed above (based on 95% two-sided confidence limits)

- **a)** is 1.6
- **b)** is 4.3
- **c)** is 12.2
- **d)** is 17.3
- **e)** cannot be determined from the given information.

Regardless of your answer to question **13. suppose for purposes of questions 14. and 15. that you judge only the first three values in the list of fitted effects above (131.9, 5.0, and 92.4) to be both statistically detectable and practically important**. In the context of this study, small y is desirable.

14. For small y one wants

- **a)** low A and low B
- **b)** low A and high B
- **c)** high A and low B
- **d)** high A and high B

15. The estimated mean surface finish measurement when A is high, B is low, and C is high

- **a)** is 1.9
- **b)** is 40.7
- **c)** is 44.0
- **d)** is 44.5
- **e)** is 133.8

A drug company ran an unreplicated 2^{5-1} fractional factorial experiment on one of its production processes, hoping to learn how to make small the response variable

$$y = \text{separated clear volume (\%) for a suspension of antibiotic after 45 days}$$

Factors and their levels were:

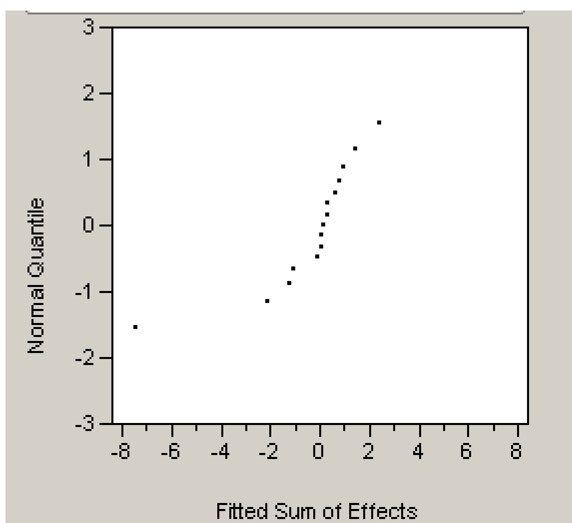
Factor	**"low"**		**"high"**
A- Preparation Method	Old	vs	New
B- Sugar Content	50%	vs	60%
C- Antibiotic Level	8%	vs	16%
D- Aerosol	.4%	vs	.6%
E- CMC	.2%	vs	.4%

As it turns out, the recommendations of the text and lecture were not followed in the choice of which 16 combinations of levels of the 5 factors to run in the experiment. Instead, the generator

$$E \leftrightarrow ABC$$

was employed.

The 16 values of y were listed in Yates order as regards factors A,B,C, and D and run through the Yates algorithm. A normal plot of the last 15 of the estimates produced by the algorithm is below.



The values of the 4 largest (in absolute value) fitted sums of effects were in fact

$$d_2 + alias = -7.4, \quad b_2 + alias = 2.4$$

$$abc_{222} + alias = -2.1, \quad cd_{22} = 1.4$$

Use this information in answering questions **16.** through **20.**

16. For purposes of making firm conclusions about how to run the process in order to make y small, this experiment is

- **a)** weakened by its lack of replication.
- **b)** weakened by the fact that it is only a *fractional* factorial study.
- **c)** weakened by the nonstandard choice of generator.
- **d)** Exactly 2 of **a)**, **b)**, and **c)** are correct completions of the sentence.
- **e)** All of **a)**, **b)**, and **c)** are correct completions of the sentence.

17. The choice of generator $\text{E} \leftrightarrow \text{ABC}$ means that in the running of the experiment

- **a)** when A,B,C, and D are all at their high levels, E will be at its high level.
- **b)** when A,B,C, and D are all at their low levels, E will be at its low level.
- **c)** when A and B are at their high levels and C and D are at their low levels, E will be at its high level.
- **d)** Exactly 2 of **a)**, **b)**, and **c)** are correct completions of the sentence.
- **e)** All of **a)**, **b)**, and **c)** are correct completions of the sentence.

18. The choice of generator $\text{E} \leftrightarrow \text{ABC}$ means that in the analysis of experimental results

- **a)** the E main effect is confounded with only the overall mean.
- **b)** the E main effect is confounded with only the ABCD 4-factor interaction.
- **c)** the E main effect is confounded with only the ABC 3-factor interaction.
- **d)** the E main effect is confounded with 2 other 2^5 factorial effects.
- **e)** the E main effect is confounded with 3 other 2^5 factorial effects.

19. The normal plot on page 7

- **a)** suggests that as few as one fitted sum of effects is clearly statistically detectable.
- **b)** is not at all as expected, since it rises but fails to fall back down to its original level as one looks left to right on the plot.
- **c)** is useless because not all 16 of the values produced by the Yates algorithm have been plotted.
- **d)** suggests that the standard deviation of y for a fixed combination of levels of factors A through E could be as large as 100.
- **e)** None of **a)** through **d)** are correct completions of the sentence.

20. The first fitted sum of effects produced by the Yates algorithm for the company's data (the one not included on the plot on page 7) was 37.6. Suppose that you were to judge only this and the largest (in magnitude) three values on the bottom of page 7 (the -7.4, the 2.4, and the -2.1) to be statistically detectable. Making the simplest possible interpretation of the 4 values from the Yates algorithm, what mean y do you predict for the 2^5 combination of levels "acd"?

- **a)** 25.7
- **b)** 29.9
- **c)** 30.5
- **d)** 40.5
- **e)** none of the above