IE 361 Exam 1
Fall 2008

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

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Name (Signed) Date

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Name (Printed)

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. "Process Improvement"
a) is promoted in modern business contexts through a variety of programs known by names ranging from "Total Quality Management" to "Six Sigma."
b) is of concern in service industries.
c) is of concern in manufacturing industries.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) All of the responses a) through c) are correct completions of the sentence.

2. As typically used in the context of modern business process improvement paradigms, the word "control" refers to
a) an activity that is fundamentally statistical.
b) an activity having to do with process monitoring, aimed at verifying that no process change is taking place.
c) activities undertaken only by upper management.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) All of the responses a) through c) are correct completions of the sentence.

3. A straight-line trend "up" on a run chart of measured diameters of axels produced by a turning process suggests that for samples of, say, $n = 10$ consecutive axel diameters y,
a) sample means $\bar{y}$ will increase approximately linearly with time.
b) sample standard deviations s will increase approximately linearly with time.
c) *both* sample means $\bar{y}$ *and* sample standard deviations s will increase approximately linearly with time.
d) *neither* sample means $\bar{y}$ *nor* sample standard deviations s will change with time.
e) nothing definitive can be said about what will happen to sample means $\bar{y}$ or standard deviations s.

4. Measurement validity, precision, and accuracy
a) are all quantified in a gauge R&R study.
b) can all be improved through careful calibration studies.
c) in a statistical study can all be improved through increased samples sizes.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) None of the responses a) through c) are correct completions of the sentence.

5. When two different devices are used to each make multiple measurements on the same unknown measurand
a) the device biases can be compared.
b) the device precisions can be compared.
c) the two individual biases can be evaluated.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) All of the responses a) through c) are correct completions of the sentence.

6. Unit-to-unit variation in a real characteristic of items produced on a production line can be quantified by a standard deviation of $\sigma_x = .1$, while measurement variation associated with observing that characteristic can be quantified by a standard deviation of $\sigma_{\text{measurement}} = 1.0$. Should actual unit-to-unit variation double (to $\sigma_x = .2$) one should expect observed variation in the characteristic (seen in single measurements made on different units and quantified by a standard deviation) to

a) decrease.
b) remain the same.
c) increase by about 1.5%.
d) increase by about 50%.
e) increase by about 100%.

Fact: The upper 2.5% point of the $F_{4,4}$ distribution is about 9.60.

Viscosities of paint samples are measured by a paint manufacturer using a single "viscometer" in units of "Krebs." Viscosities of specimens drawn from two different batches of paint made from the same formula are measured (once per specimen). $n_1 = 5$ specimens from the first batch and $n_2 = 5$ specimens from the second batch have sample means and standard deviations of measured viscosities $\bar{y}_1 = 90.2$ Krebs, $\bar{y}_2 = 92.3$ Krebs, $s_1 = .7$ Krebs, and $s_2 = .4$ Krebs.

7. Based on 95% confidence limits made from the values above, one can conclude
a) that there is a clear difference in *both* average and variability of viscosity for specimens from these two batches.
b) that there *is a* clear difference in average viscosity for specimens but there *is no* clear difference in variability of viscosity for specimens from these two batches.
c) that there *is no* clear difference in average viscosity but *is a* clear difference in variability of viscosity for specimens from these two batches.
d) that there is no clear difference in either average or variability in viscosity for specimens from these two batches.

8. In order to use data like those summarized before question 7 to compare mean viscosity for two paint batches, one must implicitly assume
a) that the viscometer is perfectly calibrated.
b) that the viscometer is a "linear" measurement device."
c) that the viscometer has a GCR of less than .1 for viscosity measurement.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) None of the responses a) through c) are correct completions of the sentence.

(For questions 9 and 10) Combine the information about Batch 1 given before question 7 with the following. Single specimens were drawn from $n = 9$ additional batches of paint made from this formula (you might call those Batch 3, Batch 4, … , Batch 11) and single measurements of viscosity were made. These measurements had sample mean and sample standard deviation respectively $\bar{y} = 92.8$ Krebs and $s = 1.1$ Krebs. Further, calibration studies have established that the viscometer is linear and reads about .3 Krebs high when measuring viscosity.

9. 95% confidence limits for a process mean viscosity for paint of this type

a) are $92.5 \pm .85$ Krebs .
b) are $92.8 \pm .85$ Krebs .
c) are $93.1 \pm .85$ Krebs .
d) can be determined from the given information, but none of answers a) through c) are correct.
e) can not be determined from the given information.

10. Approximate 95% confidence limits for a batch-to-batch standard deviation of actual viscosity

a) can not be determined from the given information.
b) are .23 Krebs and 33.3 Krebs .
c) are .44 Krebs and 5.31 Krebs .
d) are .74 Krebs and 2.11 Krebs .
e) None of responses a) through d) is a correct completion of the sentence.

(For questions 11 and 12) Continue the paint production context of questions 7 through 10. Below is part of a `JMP` report from a "one-way random effects" analysis of a study where 4 specimens were drawn from each of 5 different batches of paint, and viscosity was measured. (The nominal variable `Batch` was used in the `Fit Model` routine as a "random" factor with response `Viscosity`.)

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Batch	1.1699339	0.6639375	0.5721457	-0.457468	1.7853431	53.916
Residual		0.5675	0.2072217	0.3096762	1.3593601	46.084
Total		1.2314375				100.000

11. In units of Krebs, 95% confidence limits for the standard deviation of batch mean viscosities

a) are not available based on the given information.
b) are 0 and 1.34.
c) are 0 and 1.79.
d) are .56 and 1.17.
e) are .31 and 1.36.

12. In units of Krebs, 95% confidence limits for the standard deviation of measured viscosities if a single specimen were to be retested many times

a) are not available based on the given information.
b) are 0 and 1.34.
c) are 0 and 1.79.
d) are .56 and 1.17.
e) are .31 and 1.36.

Below is an ANOVA table from a gauge R&R study where the same optical gauge was used to measure diameters of $I = 10$ small plastic parts, $m = 3$ times each, by $J = 4$ different operators. The original data were in 10^{-3} inches.

ANOVA Table

Source	*SS*	*df*	*MS*
Parts	27.0	9	3.00
Operators	6.0	3	2.00
Parts×Operators	86.4	27	3.20
Error	96.0	80	1.20
Total	215.4	119	

13. Based on the values in the table above, a single number estimate of the repeatability standard deviation, $\sigma_{\text{repeatability}}$,

a) can not be determined.
b) is $.79 \times 10^{-3}$ inch.
c) is 1.10×10^{-3} inch.
d) is 1.35×10^{-3} inch.
e) is 1.73×10^{-3} inch.

14. In this context, an estimate of $\sigma_{\alpha\beta}$ turns out to be about .25 times an estimate of σ, while an estimate of $\sigma_{\text{reproducilbility}}$ is about .72 times this estimate of σ. This suggests that

a) reproducibility variation is smaller than repeatability variation.
b) operator "nonlinearities" are not the largest contributor to reproducibility variation.
c) one should not hope that improving operator-to-operator measuring consistency will produce an order-of-magnitude improvement in measurement precision.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) All of the responses a) through c) are correct completions of the sentence.

15. In this context, specifications on the part diameter being checked were

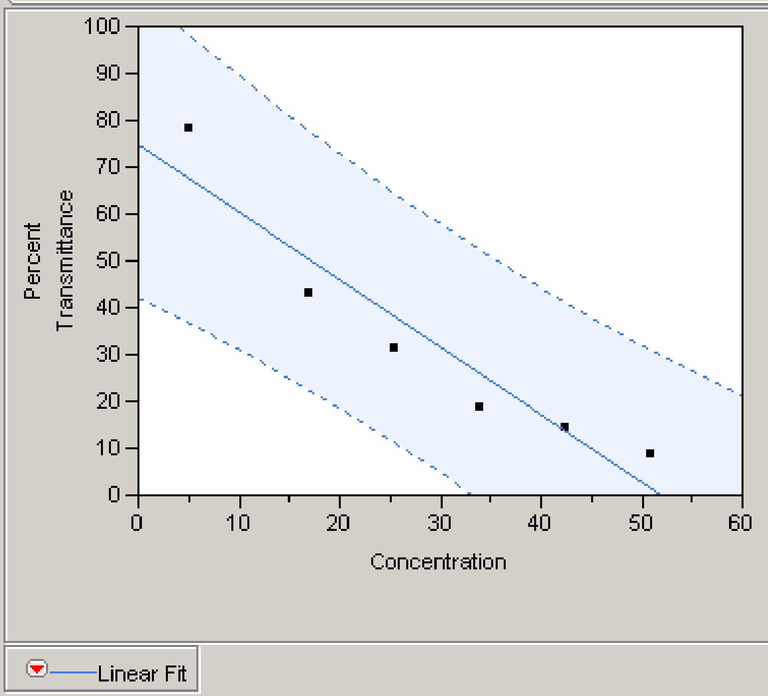
$$\textit{some value} \pm 2 \times 10^{-3} \text{ inch}$$

and it turns out that approximate 95% confidence limits on $\sigma_{\text{R\&R}}$ based on the ANOVA table are 1.17×10^{-3} inch to 1.60×10^{-3} inch. Approximate 95% confidence limits for a precision to tolerance ratio here

a) are 1.76 and 2.40 and indicate that the gauge is clearly adequate for checking conformance to these specifications.
b) are 1.76 and 2.40 and provide no definitive conclusion about the adequacy of the gauge for checking conformance to these specifications.
c) are 1.76 and 2.40 and indicate that the gauge is clearly *not* adequate for checking conformance to these specifications.
d) can be computed from the information given but are not 1.76 and 2.40.
e) None of the responses a) through d) is a correct completion of the sentence.

Below is a part of a JMP report from the analysis of a calibration data set found at
http://facultystaff.richmond.edu/~rdominey/301/Calibration3.html
A chemical analysis for copper content (in ppm) was made by means of flame atomic absorption spectroscopy. $n=6$ standards of concentration x were tested and percent transmittance values, y, were observed. Use the information on this report to answer questions **16** and **17**. (The solid line is the least squares line fit to the data and the dotted ones give 95% prediction limits for a new y at each x.)

Bivariate Fit of Percent Transmittance By Concentration



Linear Fit

Percent Transmittance = 74.613548 - 1.4447818*Concentration

Summary of Fit

RSquare	0.904622
RSquare Adj	0.880778
Root Mean Square Error	8.83443
Mean of Response	32.45
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	2960.9864	2960.99	37.9384
Error	4	312.1886	78.05	Prob > F
C. Total	5	3273.1750		0.0035*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	74.613548	7.737382	9.64	0.0006*
Concentration	-1.444782	0.234565	-6.16	0.0035*

16. The plot suggests that
a) there is some question whether y should really be treated as linear in x over the whole range of concentrations 5 ppm to 51 ppm.
b) if one does treat y as approximately linear in x, the repeatability standard deviation associated with measuring transmittance is large.
c) if one does treat y as approximately linear in x, the concentration corresponding to a read value of percent transmittance is very poorly determined.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) All of the responses a) through c) are correct completions of the sentence.

17. 95% confidence limits for a concentration, x, associated with a 40% transmittance are
a) roughly 1.5 ppm to 43.5 ppm.
b) roughly 23.9 ppm $\pm\ 2(8.8)$ ppm.
c) -1.445 ppm $\pm 2.776(.2345)$ ppm.
d) 74.61 ppm $\pm 2.776(7.738)$ ppm.
e) 5.3 ppm to 25.4 ppm.

18. In a "gauge R&R" study where J operators each make m "Go/No-Go" calls on parts,
a) for a single part, perfect "repeatability" means that a given operator makes all "Go" calls or makes all "No-Go" calls.
b) for a single part, perfect "reproducibility" means that every operator makes the same number of "Go" calls.
c) across I parts, perfect "R&R" requires that each part has the same number of "Go" calls.
d) Exactly 2 of the responses a) through c) are correct completions of the sentence.
e) All of the responses a) through c) are correct completions of the sentence.

(For questions 19-20) Here is a small part of a data set from a study of Go/No-Go inspection. Each operator (without being aware that parts were being re-inspected) made 50 Good/Defective calls on each part represented below in the course of regular visual inspections. The values in the table are $\hat{p}$ values (fractions of "Defective" calls made by the operators).

	Operator 1	Operator 2
Part 1	.10	.20
Part 2	.20	.28
Part 3	.14	.10
Part 4	.08	.16
Part 5	.62	.50

19. Considering only Part 1, approximate 95% confidence limits for the difference in long run fractions of "Defective" calls made by the two operators (say, Operator 2 minus Operator 1)
a) are $.10 \pm .01$.
b) are $.10 \pm .14$.
c) are $.10 \pm .15$.
d) can not be determined from the given information.
e) can be determined from the given information, but none of answers a) through c) are correct.

20. Presuming that the 5 parts represented in the table are a random sample of parts the operators will inspect, 95% confidence limits for comparing the average (across all parts) fraction (across many calls) of "Defective" calls for Operators 1 and 2 (Operator 2 minus Operator 1)
a) are $.02 \pm .12$ and provide clear evidence that Operator 2 tends to make more "Defective" calls that Operator 1.
b) are $.02 \pm .12$ and provide clear evidence that Operator 2 tends to make fewer "Defective" calls than Operator 1.
c) are $.02 \pm .12$ and provide no clear evidence about which operator tends to make the most "Defective" calls.
d) can be determined from the information provided, but are not close to $.02 \pm .12$.
e) None of the responses a) through d) above is a correct answer.

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Fall 2008

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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**
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1. "Common cause variation"

a) produces some level of variation in plotted values on any properly functioning control chart.
b) forms a baseline against which one attempts to judge the presence or lack of process instability.
c) can typically only be reduced through fundamental changes in how a process is configured or operated or observed.
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. Comparison of a plotted statistic Q to control limits for it

- tells one when to physically intervene in the operation of a process.
- tells one when intervention in the operation of a process is not justified.
- tells one when process output is and is not meeting engineering requirements.
- is sensible only after engineering specifications for process output have been established.

a) None of the above is a correct completion of the sentence.
b) Exactly one of the above is a correct completion of the sentence.
c) Exactly two of the above are correct completions of the sentence.
d) Exactly three of the above are correct completions of the sentence.
e) All of the above are correct completions of the sentence.

3. If a production process has been physically stable for some time

- a control chart set up to monitor it may nevertheless produce out-of-control signals because of measurement process instability.
- process monitoring should cease and the corresponding resources be redirected.
- process improvement efforts can have no further positive effect on its behavior.
- common cause variation is necessarily small enough as to be negligible.

a) None of the above is a correct completion of the sentence.
b) Exactly one of the above is a correct completion of the sentence.
c) Exactly two of the above are correct completions of the sentence.
d) Exactly three of the above are correct completions of the sentence.
e) All of the above are correct completions of the sentence.

Below are sample means and ranges from 10 samples of size $n = 3$. Use the information from these samples to answer questions 4 through 6.

Sample	1	2	3	4	5	6	7	8	9	10	Sum
$\bar{x}$	8.4	9.4	7.6	12.5	10.5	9.0	14.1	11.7	10.6	9.0	102.8
R	6.6	4.2	7.1	4.2	3.1	1.8	11.9	2.3	3.6	15.1	59.9

4. Consider standards given control charting for both $\bar{x}$ and R, with standards $\mu = 10.0$ and $\sigma = 3.0$.

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

5. Consider retrospective control charting for both $\bar{x}$ and R.

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

6. Ignore any lack of stability that you found indicated by the ranges on the previous page and use the values there to estimate σ. Based on this estimate, in turn set an upper control limit for future sample standard deviations (s) based on samples of size $n = 5$. (Remember that the samples represented in the table were of size $n = 3$.) This UCL_s is closest to

a) 17.40
b) 15.42
c) 8.05
d) 7.39
e) 6.95

7. The values of "control chart constants" in Table A.1 of *SQAME* suggest that for sampling from a particular normally distributed stable process, as sample size n increases

a) the mean size of sample ranges will increase without bound.
b) the mean size of sample standard deviations will approach that of the population standard deviation.
c) Both a) and b) are correct completions to the sentence.
d) Neither a) nor b) is a correct completion to the sentence.

8. Suppose that process parameters are $\mu = 0.0$ and $\sigma = 2.0$ for the diameters of some axels turned on a particular lathe (where units are 10^{-4} inch above some nominal value). Suppose further that axel diameters are normally distributed and specifications on diameters are 0.0 ± 2.0 inch. A sample of $n = 7$ of these axels will be produced. Below are 3 statements about what can be expected to happen in this production. How many of them are true?

- There is an approximately 68% chance that the first diameter produced meets specifications.
- The chance that all 7 diameters produced meet specifications is less than 10%.
- By the Chebyschev inequality of Stat 231, the chance is large (75% or more) that the sample median diameter, $\tilde{x}$, is between -2.0 and 2.0.

a) All 3 are correct.
b) Exactly 2 are correct.
c) Exactly 1 is correct.
d) None are correct.
e) Not enough information is given to tell how many are correct.

9. In a large insurance company claims processing center, a study of the accuracy with which a particular class of claims is handled (as judged by a specially trained company auditor) indicates that about 10% of claims of this type are seriously mishandled by ordinary adjustors. Ongoing training of adjustors is instituted in an effort to reduce this mishandling rate, and monthly sampling of cases will be done to monitor the fraction of improperly handled claims. Suppose that a standards-given control chart will be used in the monitoring.

a) A chart based on sample size $n = 50$ will allow for eventual indication of a process degradation, but not a process improvement.
b) A chart based on sample size $n = 100$ will allow for eventual indication of either a process degradation or a process improvement.
c) A chart based on sample size $n = 100$ will typically be more sensitive to process degradation than will be one based on a sample size $n = 50$.
d) Exactly two of a) through c) are correct completions of the sentence.
e) All of a) through c) are correct completions of the sentence.

10. An ultrasound non-destructive evaluation technique is used to inspect jet engine turbine blades of a common age in a fleet of Boeing 737's owned by an airline. The numbers of blades tested and numbers of blades determined to have serious internal cracks in 10 consecutive one-month periods are below.

Month	1	2	3	4	5	6	7	8	9	10	**Sum**
Tested	100	80	60	100	120	120	60	80	60	100	**880**
With Cracks	2	1	1	1	0	2	0	3	0	2	**12**

The data in the table

a) provide no evidence of change over time in the fraction of turbine blades in the fleet with detectable serious internal cracks.
b) provide clear evidence of a degradation in turbine blades in the fleet if the historical standard is 1% of blades failing this inspection.
c) are an example of "mean non-conformities per unit" 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.

11. In the context of problem 10, instead of simply calling a blade "non-conforming" if any serious internal cracks are detected, one might instead count total cracks detected in each month's inspections (where a single blade may account for more than one crack). If the historical standard is that 1% of blades have detectable serious internal cracks,

a) based on a Poisson distribution, a sensible mean number of detectable cracks per blade under historical standard conditions is $-\ln(.99) = .0101$.
b) then 100 blades producing 4 detectable cracks spread among 4 blades would produce an "out of control" signal on the basis of the 4 blades, but not on the basis of the 4 cracks total.
c) then 100 blades producing 4 detectable cracks spread among 4 blades would produce an "out of control" signal on the basis of the 4 cracks total, but not on the basis of the 4 blades with cracks.
d) Both a) and b) are correct completions of the sentence.
e) Both a) and c) are correct completions of the sentence.

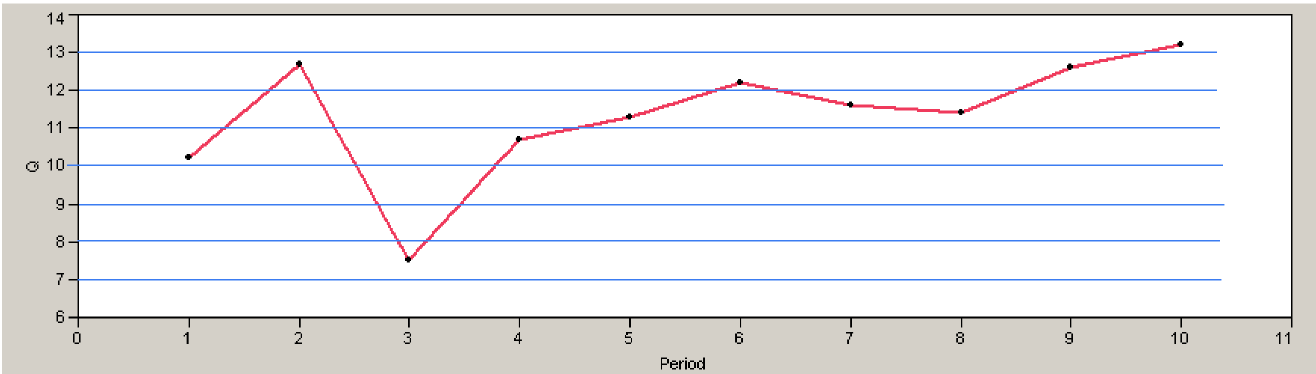
12. "Stratification"

- can occur when systematically different process streams are sampled in regular fashion and the systematic differences are ignored in control charting.
- can lead to apparently "super-stable" control charting results.
- can mask process problems that should be addressed.
- is a potential concern in manufacturing problems, but not in service contexts.

a) All of the above are correct completions of the sentence.
b) Exactly three of the above are correct completions of the sentence.
c) Exactly two of the above are correct completions of the sentence.
d) Exactly one of the above is a correct completion of the sentence.
e) None of the above is a correct completion of the sentence.

13. Suppose that for some process summary statistic Q, a standard mean is $\mu_Q = 10.0$ and a standard standard deviation is $\sigma_Q = 1.0$. A series of observed values of this statistic is listed and then plotted below.

Period, t	1	2	3	4	5	6	7	8	9	10
Q_t	10.2	12.7	7.5	10.7	11.3	12.2	11.6	11.4	12.6	13.2



A Shewhart chart using the Western Electric Rules is used to do process monitoring. At what period is the process first declared to be "out of control"?

a) at period 3
b) at period 8
c) at period 9
d) at period 10
e) None of a) through d) is correct.

14. Below are 3 statements about average run lengths for a process monitoring scheme. How many of them are true?

- Ideally, the ARL for a monitoring scheme would be infinity for standard process behavior.
- Ideally, the ARL for a monitoring scheme would be 1.0 if there is any change from standard process behavior.
- "Nearly ideal" ARLs for a monitoring scheme can only be had for the price of very large sample sizes.

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

15. How many of the following statements about "process control" methods are true?

- "Control" methods are an essential part of Six Sigma programs.
- Unless action is taken on out-of-control signals, a control chart contributes nothing toward good process behavior.
- An engineering feedback control algorithm prescribes exactly what changes to make in a manipulated variable (some process physical parameter) on the basis of measurements from the process.
- Both statistical process control methods and engineering feedback control methods aim to produce the best possible behavior for a fixed process configuration (as opposed to guiding experimental search for new and better process structures).

a) All of the above are true statements.
b) Exactly three of the above are true statements.
c) Exactly two of the above are true statements.
d) Exactly one of the above is a true statement.
e) None of the above is a true statement.

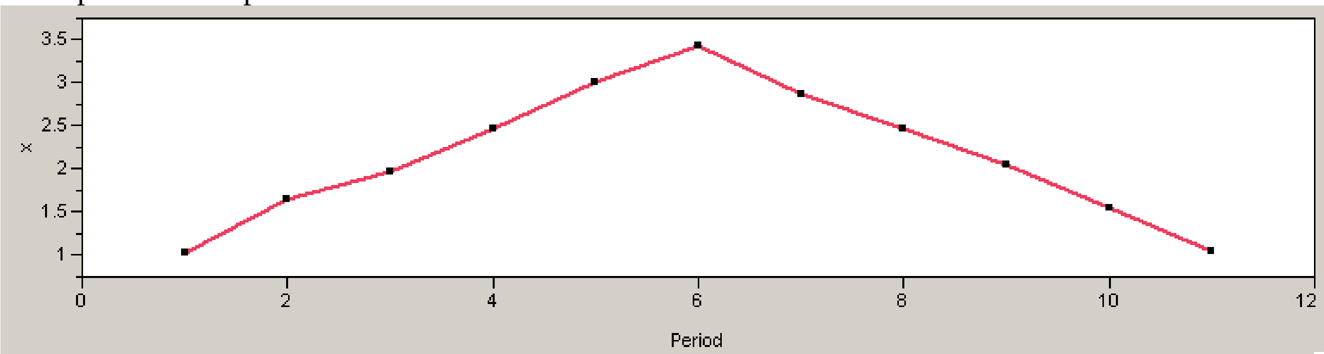
16. 11 consecutive samples of size $n = 1$ from a process are as below

Sample	1	2	3	4	5	6	7	8	9	10	11	Mean
x	1.04	1.65	1.98	2.47	3.02	3.43	2.88	2.48	2.06	1.56	1.05	2.147
MR		.61	.33	.49	.55	.41	.55	.40	.42	.50	.51	.477

Further,

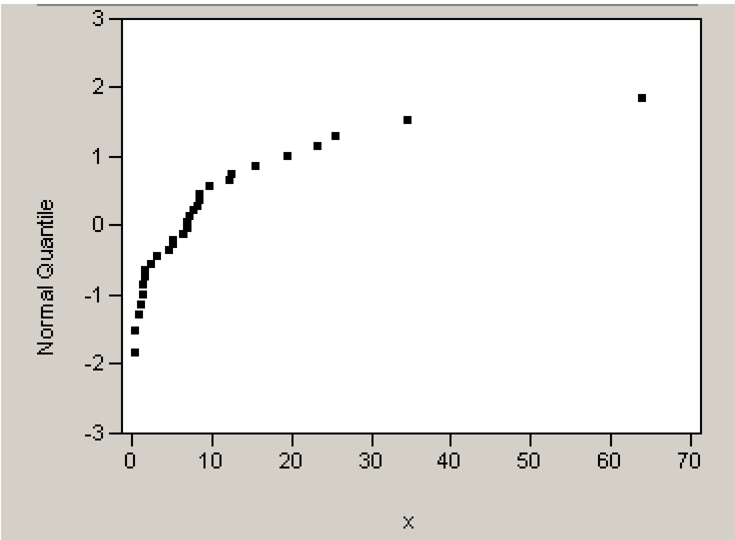
$$.477/1.128 = .423 \quad \text{while} \quad s = .789$$

and a plot of these points is



a) .423 is the best available estimate of σ, but neither .423 nor .789 appears to be sensible as a measure of process short term variability.
b) .789 is the best available estimate of σ, but neither .423 nor .789 appears to be sensible as a measure of process short term variability.
c) If instead of reversing itself at period 6 the trend in the data had continued unabated, s would have been smaller than the reported value of .789.
d) Both a) and c) are true.
e) Both b) and c) are true.

17. Below is a normal plot of a sample of size $n = 40$ measurements of a critical part dimension taken from items produced on a milling machine.



This plot

a) shows clearly that the process was not stable over the data collection period.

b) indicates that C_{pk} will be a practically meaningful measure of performance for this process.

c) shows that the process distribution of the part dimension is "short-tailed to the left" (or "long-tailed to the right") relative to the shape of a normal distribution.

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.

Thicknesses (in cm) of a batch of $n = 9$ machined stainless steel boiler nozzles have $\bar{x} = 1.6272$ cm, $s = .0281$ cm, $\min x_i = 1.575$ cm, and $\max x_i = 1.655$ cm. We'll assume that specifications on this thickness are $1.625 \pm .050$ cm and that the machining process is physically stable.. Use these facts to answer questions 18 through 20.

18. How "sure" should one be that a 10th nozzle thickness will be between 1.575 cm and 1.655 cm?

a) 70%

b) 80%

c) 90%

d) 95%

e) None of the above are close to correct.

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

a) are .401 and 1.136.

b) are .426 and 1.105.

c) are .214 and .920.

d) are .271 and .863.

e) None of the above are close to correct.

20. Again assuming thickness to be normally distributed, one can be 95% sure that 99% of all thicknesses

a) are $1.6272 \pm 2.306(.0281)$.

b) are $1.6272 \pm 3.355(.0281)$.

c) are $1.6272 \pm 4.581(.0281)$.

d) are $1.6272 \pm 4.633(.0281)$.

e) None of the above are close to correct.

IE 361 Exam 3
Fall 2008

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

____

Name Signed **Date**

____

Name Printed

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**

The 1983 article "On the Propagation of Error in Air Pollution Measurements" by Evans, Cooper and Kinney uses as an example the measurement of the concentration of particles in air as determined by a high-volume air sampler (that draws air through a highly effective filter). This quantity is

$$C = \frac{D}{F \cdot T}$$

where D is the change in mass of the filter over the collection period (in μg), F is the average flow rate during the collections period (in m^3/min), and T is the length of the collection period (in min). Representative means and standard deviations for the variables $D, F,$ and T (derived from a Harvard School of Public Health study of air pollution and lung function) were as below.

Variable	Mean	Standard Deviation
D	1.34×10^5	571
F	1.50	.106
T	1.44×10^3	3.00

1. Based on the values in the table above what "$\pm 2\sigma$ uncertainty" do you suggest attaching to a measured concentration of

$$C = \frac{1.34\times10^5}{1.50\times1.44\times10^3} = 62.0 \ \ \mu\text{g/m}^3 \ \ ?$$

- **a)** 574.1 $\mu\text{g/m}^3$
- **b)** 9.6 $\mu\text{g/m}^3$
- **c)** 8.8 $\mu\text{g/m}^3$
- **d)** all of the values in **a)** through **c)** are too small.
- **e)** all of the values in **a)** through **c)** are too big.

2. **U**ncertainty in *which* measured quantity seems to be the largest contributor to uncertainty in measured concentration?

- **a)** D
- **b)** F
- **c)** T
- **d)** Not enough information has been provided to identify the biggest contributor.

3. In order to set inspection limits on the weights of packages of small nominally identical "widgets," a project group weighs $n = 20$ sets of $m = 100$ of these widgets. The $n = 20$ weights (of groups of 100 widgets) produced in the study have sample mean 100.0g and standard deviation 1.0g. Ignoring the weight of packaging (which would additionally need to be accounted for) it is sensible to set a lower inspection weight limit for packages of (NOT 100, but rather) 25 of these widgets (that might be used to make a rapid check that enough widgets have been included in a package) at

- **a)** $\left[25-2(1.0)\right]$g
- **b)** $\left[25-2(.5)\right]$g
- **c)** $\left[25-2(.2)\right]$g
- **d)** $\left[25-2(.1)\right]$g
- **e)** 25g

The article "Factorial Design of Experiments Applied to Reliability Assessment in Discontinuity Mapping by Ultrasound" by Kruger, da Silva, and Rebello reports on a study intended to improve a variable

y = a measure of infidelity of an ultrasound image (of a fixed and known 3-d geometry with sharp edges)

(small y are good) based on some choices of the details of how ultrasound scanning is done. Below are some summary statistics for repeat scans under 4 different physical set-ups processed using what we will call Algorithm #1 to convert the ultrasound signals to an image.

Set-up #1	**Set-up #2**	**Set-up #3**	**Set-up #4**
$n_1 = 2$	$n_2 = 2$	$n_3 = 2$	$n_4 = 2$
$\bar{y}_1 = 2.55$	$\bar{y}_2 = 11.40$	$\bar{y}_3 = 5.40$	$\bar{y}_4 = 8.15$
$s_1 = .07$	$s_2 = 4.95$	$s_3 = 1.13$	$s_4 = 1.20$

4. If one adopts a "one way normal model" (with constant standard deviation) as a description of y, an estimate of the standard deviation of this measure of image infidelity for any fixed set-up using Algorithm #1

- **a)** is 1.84 with 4 degrees of freedom.
- **b)** is 2.61 with 4 degrees of freedom.
- **c)** is 1.84 with 8 degrees of freedom.
- **d)** is 2.61 with 8 degrees of freedom.
- **e)** None of **a)** through **d)** is a correct completion of the sentence.

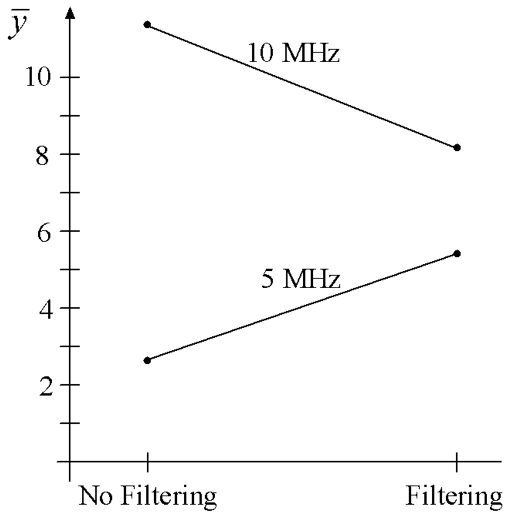
5. Set-ups #2 and #4 differ only in whether or not "Filtering" was enabled on the ultrasonic pulser/receiver. For judging whether there is there clear evidence that the mean infidelity measures for the two set-ups differ, one should compare

- **a)** 11.40 to $t \cdot s_{\text{pooled}}(.71)$ and 8.15 to $t \cdot s_{\text{pooled}}(.71)$.
- **b)** 11.40 to $t \cdot s_{\text{pooled}}$ and 8.15 to $t \cdot s_{\text{pooled}}$.
- **c)** $11.40 - 8.15$ to $t \cdot s_{\text{pooled}}(.71)$.
- **d)** $11.40 - 8.15$ to $t \cdot s_{\text{pooled}}$.
- **e)** None of **a)** through **d)** is a correct completion of the sentence.

6. An estimated standard deviation of $\hat{L} = \frac{1}{4}(\bar{y}_1 + \bar{y}_2 + \bar{y}_3 + \bar{y}_4)$ is

- **a)** $.35 s_{\text{pooled}}$
- **b)** $.50 s_{\text{pooled}}$
- **c)** $.71 s_{\text{pooled}}$
- **d)** $1.41 s_{\text{pooled}}$
- **e)** none of **a)** through **d)**.

As a matter of fact, the 4 Set-ups represented above have 2×2 factorial structure. Set-ups #1 and #2 employed no filtering while #3 and #4 used it. Set-ups #1 and #3 used a 5 MHz transducer while #2 and #4 employed a 10 MHz transducer. The 4 means from the table above are plotted on an interaction plot on the following figure.



As it turns out, appropriate 95% "margins of error" for the means plotted above are ± 5.1.

7. Based on the plotted means,

a) fitted "Filtering" main effects are smaller in magnitude than fitted "Transducer" main effects.
b) fitted "Filtering by Transducer" interactions are so small as to not be visible.
c) the fitted overall mean $\bar{y}_{..}$ is near 0.
d) None 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. Based on the plotted means *and* the 95% margins of error,

a) "Filtering" main effects are clearly statistically detectable.
b) "Transducer" main effects are clearly statistically detectable.
c) "Filtering by Transducer" interactions are clearly statistically detectable.
d) None 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.

9. If the present ± 5.1 margins of error for the plotted means were considered too large to allow adequate understanding of the effects of the "Filtering" and "Transducer" factors, one might collect additional data. Which of the following are true about such data collection?

a) Additional data collection for the 4 Set-ups would necessarily eventually provide substantially smaller margins of error for the means.
b) Additional data collection for the 4 Set-ups would necessarily eventually provide substantially smaller values of s_{pooled}.
c) Enough additional data collection would necessarily eventually make all main effects and interactions statistically detectable.
d) Exactly two of responses **a)**, **b)**, and **c)** are correct.
e) All of responses **a)**, **b)**, and **c)** are correct.

The ultrasound study actually involved not only the factors "Filtering," and "Transducer," but the factor "Algorithm" as well (a second algorithm was also used to convert ultrasound signals to images). Although the article is not explicit on this point, we will assume that each physical ultrasound scan was processed using only one of the algorithms. A summary of all the data collected in the study is on the next page.

Combination	Level of A (Transducer)	Level of B (Filtering)	Level of C (Algorithm)	$\bar{y}$	s
(1)	5 MHz	without	1	2.55	.07
a	10 MHz	without	1	11.40	4.95
b	5 MHz	with	1	5.40	1.13
ab	10 MHz	with	1	8.15	1.20
c	5 MHz	without	2	11.30	.42
ac	10 MHz	without	2	21.15	.07
bc	5 MHz	with	2	15.50	.14
abc	10 MHz	with	2	18.40	2.82

All sample sizes represented by the table are $m = 2$, and here $s_{\text{pooled}} = 2.11$ with 8 degrees of freedom.

10. It is fairly obvious from the above table (and before any formal analysis) that (at least for this object scanned using this equipment in the present fashion)

- **a)** the second algorithm is worse than the first.
- **b)** the second algorithm produces more consistent results in terms of this measure of image infidelity than the first and a "constant σ" assumption may not be a great one here.
- **c)** Both **a)** and **b)** are correct completions of the sentence.
- **d)** Neither **a)** nor **b)** is a correct completion of the sentence.

Even if you considered **b)** of **10.** to be correct, henceforth operate under a constant standard deviation model.

11. A "$\pm$ margin of error" to associate with any of the sample means in the table above based on 95% confidence limits

- **a)** is 2.43.
- **b)** is 3.44.
- **c)** is 4.87.
- **d)** is smaller in magnitude than **a)** above.
- **e)** is larger in magnitude than **c)** above.

The "Cycle #2" column in the usual table made when using the Yates algorithm is below.

27.50

66.35

11.60

12.75

$-.40$

1.45

-6.10

-6.95

Complete the Yates algorithm and use your results in what follows.

12. The sign of a_2 produced by the Yates algorithm

a) is negative, but this has no practical interpretation.
b) is positive, but this has no practical interpretation.
c) is negative and indicates that the 10 MHz transducer produced better (smaller) values of y overall.
d) is positive and indicates that the 10 MHz transducer produced worse (bigger) values of y overall.

13. The "$\pm$ margin of error" for any of the fitted effects you computed (based on 95% two-sided confidence limits)

a) is 1.22
b) is 2.44
c) is 4.88
d) is smaller than **a)** above.
e) is larger than **c)** above.

14. Regardless of how you answered **13.**, apply a ± 1.0 margin of error criterion and judge which 2^3 factorial effects are detectable. These are

a) the overall mean, A, B, and C main effects only.
b) the overall mean, A and B main effects only.
c) the overall mean, A and C main effects only.
d) the overall mean, B and C main effects only.
e) the overall mean, A and C main effects and AB interactions.

15. Using a fitted model that includes only A and C main effects and AB interactions, what value of y should one predict for a scan of the test geometry using a 5 MHz transducer, no filtering, and the first algorithm?

a) 2.07
b) 2.20
c) 2.55
d) 3.83
e) None of **a)** through **d)** is close to being correct.

Now suppose hypothetically (not because this was the case in the actual study) that there were 2 additional factors 2-level factors, D and E, with levels varied in the collection of the data represented at the top of page 6. In fact, suppose that the 8 set-ups indicated there as regards levels of A,B, and C, had corresponding levels of D and E derived from the choice of generators

$$D \leftrightarrow AB \text{ and } E \leftrightarrow AC$$

16. In this hypothetical scenario, what levels of D and E were used in the collection of the data represented on the first row of the table on page 6?

a) low D and low E
b) low D and high E
c) high D and low E
d) high D and high E
e) It is impossible to tell from the given information.

17. The choice of generators $D \leftrightarrow AB$ and $E \leftrightarrow AC$ means that in the analysis of experimental results

- **a)** every effect will have 3 aliases.
- **b)** the D main effect is confounded with only the AB 2-factor interaction.
- **c)** the A main effect is confounded with only the BD and EC 2-factor interactions.
- **d)** the E main effect is confounded the AC 2-factor interaction and 2 other 2^5 factorial effects.
- **e)** Exactly 2 of **a)** through **d)** are correct completions of the sentence.

18. If I judge the fitted sums of effects that appear on the 1st, 2nd, 4th and 5th rows of the last column of the Yates calculations to be statistically detectable, in this hypothetical context the simplest interpretation available is that

- **a)** the overall mean and A, C, and D main effects are detectable.
- **b)** the overall mean and A and C main effects and AB interactions are detectable.
- **c)** the overall mean and A main effects and DE interactions and CD interactions are detectable.
- **d)** None of **a)**, **b)**, and **c)** is a correct completion of the sentence.

19. Making the simplest possible interpretation of the outcome that the fitted sums of effects that appear on the 1st, 2nd, 4th and 5th rows of the last column of the Yates calculations are statistically detectable, what mean y do you predict for the 2^5 combination of levels "de"?

- **a)** 2.07
- **b)** 2.20
- **c)** 2.55
- **d)** 3.83
- f) None of a) through d) is close to being correct.

20. There is no need to normal plot the 8 values produced by the Yates algorithm in this hypothetical 2^{5-2} context because

- **a)** the central limit theorem already guarantees that sample means $\bar{y}$ will be approximately normal.
- **b)** the method is only useful in full factorial contexts.
- **c)** there is replication somewhere in the experiment, so that it's possible to judge statistical detectability using "margins of error" for fitted sums of effects.
- **d)** Exactly 2 of responses **a)** through **c)** are correct completions of the sentence.
- **e)** None of **a)** through **c)** are correct completions of the sentence.