

**IE 361 Exam 3
Fall 2007**

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

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

In the experimental determination of the density of a particular metal specimen, a graduated cylinder is partially filled with water, the volume read, and the weight of the cylinder plus water determined. The specimen is then dropped into the cylinder and the volume (of water and specimen) and weight (of cylinder, water and specimen) are again determined. The specimen density is calculated as

$$D = \frac{W_2 - W_1}{V_2 - V_1}$$

(where the W 's are the two weights and the V 's are the two volumes). Originally, $W_1 \approx 200$ g, and $V_1 \approx 100$ cc. The metal specimen has a mass of roughly 60g and a volume of roughly 10cc. Suppose that the scale being used has an associated repeatability standard deviation of $\sigma_w = .01$ g and the repeatability standard deviation associated with the use of the graduated cylinder in this way is $\sigma_v = .3$ cc. Use this information when answering questions **1.** through **3.** below.

1. Using the "propagation of error" formula, a plausible standard deviation to associate with an experimentally determined density of this specimen

- a) is about .06g/cc.
- b) is about .25g/cc.
- c) is about .31g/cc.
- d) is about .33g/cc.
- e) is close to none of the responses a) through d) above.

2. If a specimen twice the size of the one referred to above is used in a second study to determine density, the propagation of error formula suggests

- a) the precision with which the density is determined will be improved.
- b) the precision with which the density is determined will stay the same.
- c) the precision with which the density is determined will be degraded.
- d) nothing about whether precision will improve or be degraded.

3. If one is interested in improving the precision of experimentally determined densities of specimens of this type, the propagation of error formula suggests

- a) improvement in precision of the weight measurement is most important.
- b) improvement in precision of the volume measurement is most important.
- c) improvement in precisions of the two types of measurements are about equally important.
- d) nothing about the relative importance of improving the two types of measurement.

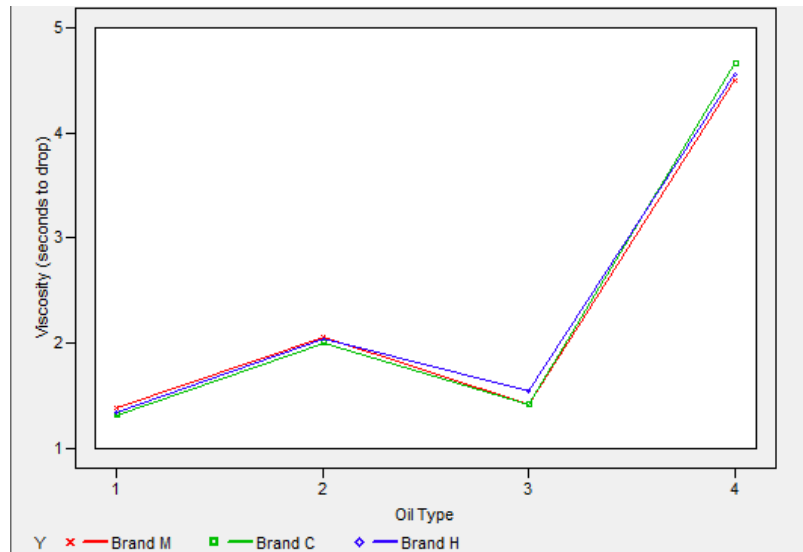
A metal drilling study was done to investigate the torque, y (ft-lb), required to rotate a drill into an aluminum alloy at various feed rates, x (in/rev). A summary of part of the data from the study is below. Use this information when answering questions **4.** through **6.** on the next page.

$x = .005$ in/rev	$x = .009$ in/rev	$x = .017$ in/rev
$n_1 = 1$	$n_2 = 4$	$n_3 = 1$
$\bar{y}_1 = 1.1$ ft-lb	$\bar{y}_2 = 2.08$ ft-lb	$\bar{y}_3 = 3.4$ ft-lb
	$s_2 = .13$ ft-lb	

4. The fact that only the $x = .009$ in/rev condition was run more than once in this part of the study
- is a basic weakness in the data collection plan.
 - means that there is no way to check on the reasonableness of the "constant variance assumption" of the usual one-way normal model.
 - means that s_2 given in the table must function as the "pooled estimate of standard deviation" for analyses based on the one-way normal model.
 - Exactly 2 of **a)** through **c)** are correct completions of the sentence.
 - All of **a)** through **c)** are correct completions of the sentence.
5. Two-sided confidence limits for $\frac{(\mu_3 - \mu_2)}{.008} - \frac{(\mu_2 - \mu_1)}{.004}$ provide a way to ask whether y changes linearly with x . (Physically, there is probably no reason to expect this to be the case.) These limits are of the form
- $-80 \pm t \cdot s_{\text{pooled}} (113,281)$
 - $-80 \pm t \cdot s_{\text{pooled}} (15,625)$
 - $-80 \pm t \cdot s_{\text{pooled}} (337)$
 - $-80 \pm t \cdot s_{\text{pooled}} (125)$
 - None of **a)** through **d)** is close to correct.
6. By the standard of two-sided 95% confidence limits, the sample means in the table are "good to within" about
- .17 ft-lb
 - .21 ft-lb
 - .41 ft-lb
 - .41 ft-lb for the first and third, .21 ft-lb for the second
 - .41 ft-lb for the first and third, .10 ft-lb for the second

An ISU student group did a viscosity study for 3 different Brands of motor oil of 4 different Types/weights. They measured the time (in seconds) required for a particular ball to drop a fixed distance through samples of oil at room temperature. Each measurement was repeated $m = 10$ times. (The students almost certainly did *not* use 10 different cans of oil of each type, so the variability that they observed was really purely repeatability variation and *likely does not reflect can-to-can variation in oil viscosity for cans of these types*. We will simply take this fact for what it is worth, and remember that strictly speaking conclusions drawn here apply to the 12 cans of oil tested, and not more generally to all cans of these types from these companies.) The pooled standard deviation from the 120 measurements made by the group was $s_{\text{pooled}} = .12$ sec. The following is a table of sample means of the measurements and there is a plot of these means on the next page. Use them in answering questions **7.** through **9.**

	Type 1 (10W30)	Type 2 (SAE30)	Type 3 (10W40)	Type 4 (20W50)
Brand M	1.385	2.066	1.414	4.498
Brand C	1.319	2.002	1.415	4.662
Brand H	1.344	2.049	1.544	4.549



7. The "2 standard deviation margin of error" associated with any single mean in the study (as representing the can from which the oil was drawn) is about .076 sec. This fact and the table and plot above suggest

- a) that there are clearly detectable viscosity differences between oil Types.
- b) that differences in viscosity between Brands for oil Types 1 and 2 are not statistically detectable.
- c) that (even if they are barely statistically detectable) Brand by Type interactions are small in comparison to Type main effects.
- 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 difference between the Oil Type 2 and Oil Type 1 average sample means is about .690 sec. This difference

- a) has a "2 standard deviation margin of error" around .076 sec, clearly indicating a detectable difference in Type 1 and Type 2 main effects.
- b) has a "2 standard deviation margin of error" around .076 sec, indicating there is no detectable difference in Type 1 and Type 2 main effects.
- c) has a "2 standard deviation margin of error" around .062 sec, clearly indicating a detectable difference in Type 1 and Type 2 main effects.
- d) has a "2 standard deviation margin of error" around .062 sec, indicating there is no detectable difference in Type 1 and Type 2 main effects.
- e) None of a) through d) is a correct completion of the sentence.

9. The "2 standard deviation margin of error" associated with differences in Brand main effects

- a) is about .054 sec
- b) is about .062 sec
- c) is about .076 sec
- d) is about .240 sec
- e) is none of responses a) through d).

10. Two-factor interactions in a two-way factorial study

- a) are measures of what that can be seen in factor combination means beyond what is explainable in terms of an overall mean and the factors acting "individually."
- b) are measures of "lack of parallelism" that would be seen on an "interaction plot" of means.
- c) are "small" for simple systems where one can say what changing levels of Factor A does to mean response without having to specify what level of Factor B is under discussion.
- 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.

Consider a hypothetical balanced 2^3 complete factorial data set with $m = 4$ observations per combination producing sample means and standard deviations as in the table below.

Combination	\bar{y}	s	$\ln s$
(1)	7	.08	-2.5
a	9	.08	-2.5
b	7	.22	-1.5
ab	9	.22	-1.5
c	11	.08	-2.5
ac	13	.08	-2.5
bc	11	.22	-1.5
abc	13	.22	-1.5

Use the values in this table in answering questions **11.** through **15.**

11. If one assumes that the experimental response variable, y , has the same standard deviation for every fixed combination of levels of the three factors A, B and C, an estimate of this standard deviation

- a) is .08
- b) is .150
- c) is .166
- d) is .22
- e) is not close to any of a) through d) above.

12. Continuing to assume that the response has the same standard deviation for every fixed combination of levels of the factors, a "margin of error" based on 95% two-sided confidence limits for any of the fitted effects produced by applying the Yates algorithm to the sample means (the \bar{y} 's)

- a) is .055
- b) is .060
- c) is .171
- d) is .310
- e) is .342

13. Still continuing under the constant standard deviation model, the Yates algorithm shows that (in terms of the factorial effects)

- a) only the A main effects on mean response are statistically detectable.
- b) only the B main effects on mean response are statistically detectable.
- c) only the C main effects on mean response are statistically detectable.
- d) only the main effects on mean response of exactly 2 of the 3 factors are statistically detectable.
- e) only the main effects on mean response of exactly 2 of the 3 factors and the corresponding 2-factor interactions are statistically detectable.

14. If one wants to entertain the possibility that variability in y for fixed levels of the factors changes combination-to-combination, a possible way to proceed is to apply the Yates algorithm to the 8 values of s (or better, the 8 values of $\ln s$) in the table. There is no "replication" of s values and thus no way to find a "margin of error" to attach to the values output in this second use of the Yates algorithm and judge statistical significance. But the more-or-less-obvious conclusion of using the algorithm to analyze response variance is that

- a) only the A main effects on response variability are large.
- b) only the B main effects on response variability are large.
- c) only the C main effects on response variability are large.
- d) only the main effects on response variability of exactly 2 of the 3 factors are large.
- e) only the main effects on response variability of exactly 2 of the 3 factors and the corresponding 2-factor interactions are large.

15. The kind of analysis outlined in questions **11.** through **14.** suggests that if one wants large mean y with small variability in y , levels of the factors should be set as

- a) A high, B low, C high
- b) A either low or high, B low, C high
- c) A high, B either low or high, C high
- d) A high, B low, C either low or high
- e) None of responses **a)** through **d)** above is appropriate.

An ISU student group did a project with a company involving the operation of a large injection molding machine. What follows is a simplification and slight modification of some aspects of that project. The company was interested in improving the output of the machine (in terms of pounds of plastic extruded per hour). In some (undisclosed) units, y is a measure of this process yield. The students considered the impact of 6 experimental factors on y . These were A (bulk density of raw material), B (amount of water added to the raw material), C (amperage supplied to the crammer/auger), D (extruder screw speed), E (extruder front end temperature), and F (extruder back end temperature). Each factor had a low and a high level. An unreplicated 2^{6-2} study produced 16 values of y . The two generators used to choose levels of Factors E and F to go with combinations of levels of Factors A through D were

$$E \leftrightarrow ABC \text{ and } F \leftrightarrow BCD$$

16. The generators above indicate that in the experimentation, when Factors A and B were at their high levels and Factors C and D were at their low levels, the levels of the other 2 factors used were

- a) E low and F low
- b) E low and F high
- c) E high and F low
- d) E high and F high
- e) unknown, but randomly chosen.

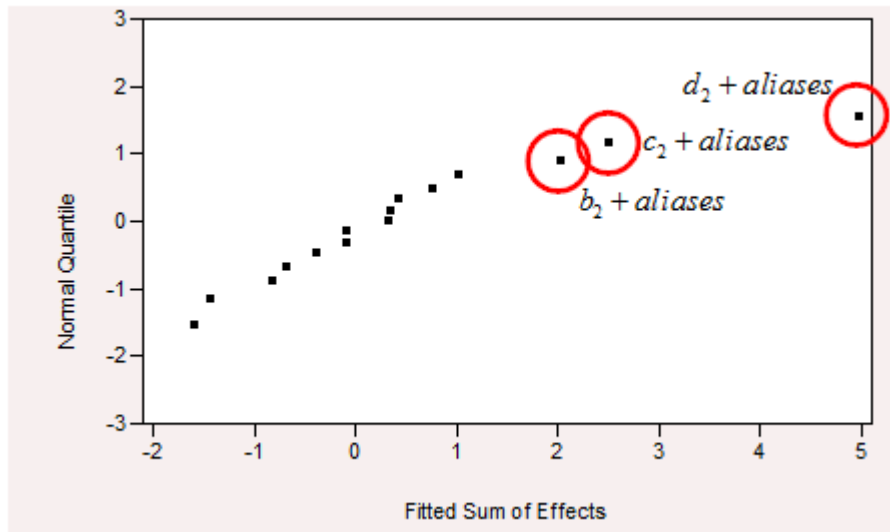
17. The "defining relation" for the study

- a) is $I \leftrightarrow ABCE$
- b) is $EF \leftrightarrow AD$
- c) is $I \leftrightarrow ABCE \leftrightarrow BCDF$
- d) is $I \leftrightarrow ABCE \leftrightarrow BCDF \leftrightarrow ADEF$
- e) is none of the answers **a)** through **d)**.

18. When the Yates algorithm is applied to the 16 values of yield, y , (placed into Yates standard order as regards levels of Factors A,B,C, and D ignoring levels of Factors E and F), a fitted sum of effects that involves the E main effect can be found in the last column of the table of calculations

- a) on the 7th row.
- b) on the 8th row.
- c) on the 15th row.
- d) on the 16th row.
- e) None of the responses a) through d) is a correct completion of the sentence.

A Normal plot of the last 15 estimates produced by the Yates algorithm when used as described in question 18. is below.



19. The message conveyed by the normal plot is that

- a) if the extruder actually behaves in a relatively simple fashion, the high level of D, and probably also the high levels of B and C should be used in order to produce large yield.
- b) there are clearly no main effects of any of the Factors A, E, and F.
- c) yield for a fixed combination of levels of Factors A,B,C,D, and E can NOT be treated as normally distributed.
- 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.

20. Suppose that long experience with the extruding machine suggests that running it with fixed levels of the experimental factors produces a long run standard deviation of yield around $\sigma = 4.0$. This can be used to develop a sensible "2 standard deviation margin of error" for any fitted sum of effects. By the standard of such a margin and the values indicated on the plot

- a) there are no statistically detectable sums of effects.
- b) only the sum of the D main effect and its aliases is statistically detectable.
- c) only the two sums of the D main effect and its aliases and the C main effect and its aliases are statistically detectable.
- d) there are three statistically detectable sums of effects corresponding to D, C, and B main effects and their respective aliases.
- e) None of the responses a) through d) are correct completions of the sentence.