**STAT 642 H.O. 8: CRD with Factorial Treatment Structure – Special Situations**

***Experiments with Unobserved Treatments:***If one or more of the treatments are not observed, , we cannot use the standard methods of analysis. One of the ***major problems is*** that the unobserved treatments will have means which cannot be estimated with the given data. This will result in the main effects containing these treatments to be non-estimable

* Ex: Suppose we have two factors A&B with 3 and 2 levels, respectively. Suppose that one of the t=6 trts is not observed, for example (A,B) = (1,1). Then we have no data associated with the trt mean . This causes problems when we try to estimate main effects for both factor A and factor B. For example,
* Ex (contd): The factor A main effect cannot be estimated because we have no data to estimate . Similarly, the factor B main effect: cannot be estimated b/c again we have no data to estimate . However, we could estimate the factor A main effect:

Four Sum of Squares from SAS: The SAS output has four types of Sums of Squares. When fitting a model with multiple effects; for example:

* SAS uses the notation:
* The Four types of Sums of Squares will be defined using the following model:
* **Type I SS:** SS for each of the terms in the model are computed in a sequential manner using the order in which they appear in the model. Type I SS are generally useful only for regression models where a polynomial model is being built from a low degree of complexity to a higher degree of complexity. *Type I SS are also used in analyzing* ***Hierarchical Nested Trt Factors***
* **Type II SS:** The Type II SS for each of the terms in the model are adjusted for every other effect in the model that is at the same or lower level. Type II SS are used in the analysis of sample survey data in which they hypotheses being tested are weighted means where weights are estimates of the population weights.
* **Type III & IV SS:** The Type III & IV SS are identical for experiments in which trts. The SS for each term is adjusted for all other effects in the model. These two are the most widely used in the analysis of experiments. When for some trt, Type IV SS adjusts factor effects by averaging over one or more common levels of the other factors. When some , Type IV SS are testing hypotheses that are most likely to have reasonable interpretations.

Approach II: Cell Means Model Using Contrasts to Test Hypotheses

The more appropriate approach when we have missing trts is to use a Cell Means Model and construct contrasts which are testing hypos that are directly of interest.

* First test for overall difference in the trts we observed (note in this example we didn’t observe trts (1,3) and (2,2))
* For testing for significant main effects and two-way interactions, we need to modify our typical contrasts. The choice of contrasts are not unique anymore, nor are they orthogonal.

***CR Factorial Experiment Augmented with Control:*** Often experiments involving factors with one factor having *a* qualitative levels and a second factor having *b* quantitative levels **with one of the levels being a 0 level** (think a placebo, no real treatment). The analysis of these types of experiments is often inappropriate. The problem arises with the treatments consisting of the cross of the levels of a qualitative factor with the 0 level of the quantitative factor. For example, say we have drugs A, B, C and were giving patients doses of (0,1,2,3) mg. Many would mistakenly conclude that we have 3\*4 = 12 unique trts. However, the trts (A,0), (B,0) & (C,0) are all the same trt (no drugs were given in any of them). Thus, we actually only have t = 3(4-1)+1 trts. **In general,** we have

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Description automatically generatedGeneral Approach to Analysis: **(1)** Analysis of (a) quantitative levels (use all the data):

(i) Fit the model: . (ii) this yields

**(2)** Analysis of Factorial Structure (do not use data from the control trt):

(i) Fit the model:

(ii) this yields and

**(3)** Analysis as a CR design with (uses all the data):

(i) fit the cell means model (ii) this yields

**STAT 642 H.O. 9: Random Effects Models and Nested Models**

***Statistical Model for CRD with Trts Constructed from Two Factors***: We'll consider 3 cases: both factors fixed, both factors random, one factor fixed & one factor random

Case 1: (Both Factors Fixed) This is what we've been dealing with typically (no need to elaborate)

Case 2: (Both Factors Random): Model: with the following assumptions

* **(i)** **(ii)**  **(iii)**  **(iv)**  **(v)**
* The above conditions yield the following results: **(1)** **(2)**  **(3)** The are identically distributed but **NOT** independent
* NOTE: multiple comparisons and contrasts are **NOT** appropriate for factors with random factor levels.

Case 3: (Mixed Factors): Model: with the following assumptions:

* **(i)** **(ii)** **(iii)** **(iv)** **(v)**
* The above conditions yield the following results: **(1)** **(2)**  **(3)** The are **NOT** ident. dist. or ind.
* We can use multiple comparisons and contrasts to investigate differences in the levels of the factor having fixed effects. **B/c F2 has random levels, we would** **evaluate the levels of F1, averaged over the levels of F2** **even when there is significant evidence of an interaction between F1 and F2**.

Table

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* Model:
* **NOTE:** the replication source of variation is nested w/in the trt combination
* For each row, place the following values under each variance component:
  + In column for **Fixed** variance component place a 0 in all rows **except** for the row where the source of variation **exactly matches** the subscripts of the **fixed** variance component. For this row, divide r\*a\*b\*c by the number of levels of the factors in the subscript of the variance component, then place the resulting number in the row of the source of variation hat **exactly matched** the subscripts of the **fixed** variance component
  + If the source of variation is **a part of or the complete subscript** of a **random** variance component, then divide r\*a\*b\*c by the number of levels of the factors in the subscript of the variance component.
  + Place a 1 in all rows under the column for

***Multiple Comparison and Contrasts in the Mixed Model***

Two Factors F1 and F2:

* Case 1: Both Factors Fixed Levels Model: for (fixed number of replications)
  + Case 1a: F1\*F2 **NOT** significant: Interaction NOT significant 🡪 marginal means are of interest. and **(2)** Tukey-Kramer HSD: State there is sig. evidence that the marginal means are different if **(3)** Dunnett's HSD: State there is sig. evidence that the control mean if
  + Case 1b: F1\*F2 significant: Want to compare the levels of F1 separately at each level of F2: For each value of compare the (a) levels of Factor F1

**(2)** Bonferroni-Tukey HSD: For each value of state there is sig. evid. that the marginal means are different if

**(3)** Bonferroni-Dunnett's HSD: " " the control mean if

* Case 2: F1-Fixed and F2-Random: Model: for with assumptions
  + Case 2a: F1\*F2 **NOT** significant: marginal means are of interest (for the fixed factor, in our example, that would be F1) **(2)** Tukey-Kramer HSD: State there is sig. evidence that the marginal means are different if

**(3)** Dunnett's HSD: State there is sig. evidence that the control mean if

* + Case 2b: F1\*F2 significant: *No difference from case 2a since the levels of F2 are random*. (Case 3, both factors random🡪 not interested in trt or marginal means)

Three Factors F1, F2, F3:

* Case1: If **all factors have random levels**, then multiple comparisons and contrasts in either trt or marginal are not of interest b/c factor levels are random.
* Case 2 All Factors Fixed: **(1)** ; **(2)** In the formulas, replace t with the appropriate number of means being compared. **(3)** In the formulas, replace r or ni with the appropriate sample side which is determined by the number of terms averaged over to obtain the point estimator.
  + Case 2(a) F1\*F2\*F3 Significant: For each combination (j,k) of the levels of (F2,F3), conduct comparisons across the levels of F1
  + Case 2(b) F1\*F2\*F3 **NOT** Significant:
    - Case 2(b)(i): F1\*F2 & F1\*F3 Significant: **(1)** For each level (j) of F2, conduct comparisons of the levels of F1 averaged over F3 & **(2)** " " (k) of F3 " " F2
    - Case 2(b)(ii): F1\*F2 Sig. F1\*F3 **NOT** sig: For each level (j) of F2, conduct comparisons of the levels of F1 averaged over F3
    - Case 2(b)(iii): F1\*F2 & F1\*F3 **NOT** sig: Conduct comparisons of the levels of F1 averaged over the other two factors
* Case 3 F1-Fixed, F2 & F3 Random: b/c the levels of F2 & F3 are random, we are only concerned with differences in the marginal trt means of the levels of F1 Model:

where and where d =

**(1)** Tukey-Kramer HSD: Sig. Evidence the marginal means are different if

**(2)** Dunnett's HSD: Sig. Evidence that the control mean if ;

* Case 4 F1 & F2 Fixed, F3 Random:
  + Case 4a: F1\*F2 **NOT** Significant: Make comparisons of differences in the marginal treatment means

Model: : with

* + Case 4b: F1\*F2 Significant: (1) Compare the treatment means across the levels of F1 separately at each level of F2

(2) Do the same for the trt means across the levels of F2 separately at each level of F1

**(3)** Comparing all ab(ab-1)/2 trt means :

***Nested Treatment Factors:*** Which tests of hypotheses and multiple comparisons to conduct depends on whether the factors are fixed or random.

* Case1: F1-Fixed Levels, F2-Fixed Levels within the levels of F1, F3 random Levels within the levels of F2
  + Model: w/conditions ;
  + To test no differences across the levels of F1: ; if Ho is rejected, construct contrasts and multiple comparisons across the levels of F1
  + To test no differences across the levels of F2(F1): ; if Ho is rejected, construct contrasts and mult. comps. across the levels of F2 separately for each level of F1.
* Case 2: F1-Fixed F2(F1)-Random; F3(F1,F2)-Random: Model:
  + To test no differences across the levels of F1: if Ho rejected, construct contrasts and mult. comps. across the levels of F1
  + To test no differences across the levels of F2(F1): ; if Ho rejected, no further comps. are relevant
* Case 3: F1, F2(F1), F3(F1,F2) – Random: Test no differences across the levels of F1: ;
  + Test no differences across the levels of F2(F1): ;

**STAT 642 H.O. 10: Fractional Factorial Designs (FF)**

Use fractional factorial b/c it's not necessary to test all possible factor-level combs to estimate the most crucial factor effects, main effects and low-order interactions

Whenever FF experiments are conducted, some effects are confounded with one another. **DEF: (Confounded effects)** Two or more experimental effects are confounded if calculated effects can only be attributed to their combined influence on the response, not to their individual ones. *Two or more effects are confounded if the calculation of one effect uses the same* ***(apart from the sign)*** *difference or contrast of the response averages as the calculation of the other effects*.

* In general when designing FF experiments, one seeks to confound either effects known to be negligible relative to the uncontrolled experimental error variation or in the absence of such knowledge, high-order interactions, usually those involving three or more factors.
* **DEF: (Design Resolution)** An experimental design is of resolution R if all effects containing (s) or fewer factors aren’t confounded with any effects containing **fewer** than R-s factors. Ex: (Resolution VII design); Main effects, two-factor interactions and three factor interactions are not confounded with each other. Main effects are not confounded with any interaction with less than 6 factors, 2-Factor interactions are not confounded with any interaction containing less than 5 factors and 3-Factor interactions aren’t confounded with any interaction containing less than 4 factors.

***Completely Randomized Fractional Factorial ( Designs*:**

Designing a Fraction of a Design : **(1)** Select p defining contrasts (none of these contrasts can be obtained by a multiplication of the other contrasts). **(2)** An additional implicit contrasts are determined by multiplying the p contrasts selected in (1). **(3)** Randomly assign +1 or -1 to the p defining contrasts, yielding a vector of all +1's or all -1's. **(4)** Select the Trts having the specified p-vector for their values in the defining contrasts. Note that there are trts selected for the experiment. Thus the data will yield estimates of effects. **(5)** The Alias sets of confounded contrasts can be obtained by using the defining and implicit contrasts. **(6)** The n factors yield a total of effects: overall mean, n main effects, two-way interactions, three way interactions,…, one n-way interaction for a total of effects. **The effects are categorized into Alias Sets each containing elements. The effects in each alias set are confounded.**

Estimating Main and Interaction Effects in a Design: Suppose we have a design with n=#of factors: , , the number of data values.

* Main Effects: Each factor only has two levels hens the estimated main effect of say is the mean difference between the data values associated with the high level of A1 and the data values associated with the low level of A1.
* Two-Way interactions: 2-way inter. btwn A1 & A2 is given by
* Three-Way and Larger Inters: The k-way inters. are obtained in a similar fashion; the formula would just be times the differences in the various sums of responses

***Designing Half Fractions of 2-Level Factorial Experiments in CR Designs*:** The highest resolution a half fraction can attain is equal to the # of factors in the experiment.

***Quarter*** More than one defining contrast is needed to partition the factor-level combinations.

* The resolution of the design equals the number of factors in the smallest defining contrast, including implicit ones.

***Screening Designs and Sequential Experimentation*:** Screening experiments are conducted in order to identify a small number of dominant factors, often with the intent to conduct a more extensive investigation involving only these dominant factors. **Ruggedness Tests** are one application of screening experiments, whose purpose is to determine environmental factor or test conditions that influence measurements obtained from the test methods.

* To allow for an estimation of experimental error, it is recommended that the design have at least 6 more test runs than the number of factors included in the experiment (only required that the number of runs in 1 more than the number of factors)
* In analyzing screening designs it is often a good idea to allow a larger than normal significance level in testing for main effects when the goal of the screening experiment is to (1) Select potentially important factors for study in future experiments or (2) Identify factors for which tighter controls will be implemented in order to obtain a more uniform product (use )

***General Method of Obtaining Aliasing*:** Let **X** be the design matrix for a given experiment. Let be the portion of the design matrix that contains the effects for which the aliases are desired and contain the columns of **X** not contained in **.** The alias matrix is then

**STAT 642 H.O. 11: Blocking Designs**

***Randomized Complete Block Design (RCBD)*:** **(1)** EU's are grouped into r blocks of mt EU's; in most cases m=1. **(2)** the mt EU's in a given block are then randomly assigned to the t trts such that m EU's are assigned to each of the t trts. There is, in essence, a CRD with m reps per trt within each of the r blocks

* Model: (in typical RCBD when m=1, there is no interaction term included in the model)
* Why not always block? 🡪 If we use r blocks, there is a loss of r-1 df from MSE. Thus, if the blocking doesn’t significantly reduce SSE, then the F-test for trt effects and multiple comparison procedures will have a reduction in precision relative to the corresponding CRD.

Advantages of a RCBD to a CRD: **(1)** The analysis is direct. A meaningful analysis can be conducted even when some of the observations are missing. **(2)** When the blocking effect is significant, the reduction in MSE affords a more powerful F-test for trt differences and a more precise estimation of the diffs. in trt means. **(3)** The RCBD is a very flexible design procedure. There is no limitation with respect to the number of trts or the number of blocks.

Disadvantages of a RCBD to a CRD: **(1)** If the number of trts (t) is large, it can be hard to obtain a homogeneous grouping of the EU's. **(2)** If there's a block by trt interaction and m = 1, then there is not, in general, a valid analysis of trt effects. Under special circumstances a partial analysis is possible. **(3)** If the block factor is not needed there will be a loss in the mower for test for a trt effect and a loss in efficiency in the construction of CI's for trt effects and means. This occurs due to a reduction in MSE df.

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Description automatically generatedRCBD Example: Note for AOV table: when m=1 becomes b/c the

Model:

* if m > 1 & m=1 with the Satterthwaite df.
* w/df=(r-1)(t-1)

*Relative Efficiency of Blocking*: ; if RE>1 then RCBD is more efficient

Suppose RE=1.25 🡪it would take 25% more obs. in a CRD to achieve the same precision

*Nonparametric Analysis of RB Designs-Friedman's Test*: If the responses are very nonnormal in distribution. The following model is appropriate:

when the following conditions are satisfied: **(1)** The N=tr random variables, , are mutually independent.

* **(2)** The have cdfs which are related by where F is a cont. cdf with unknown median **(assumes equal variances)**; is the random additive effect of the jth block and is the unknown additive effect of the ith trt. **NOTE: there is a function** friedman.test() in R.
* Testing: If we run AOV on the ranks ; reject if where is given in table A.22

***Latin Square Design (LSD)*:** An experiment where we have t unstructured trts and t2 EU's which are structured depending on the values of the two blocking variables is called a basic LSD. The square consists of **(1)** Rows: Levels of the first blocking variable **(2)** Columns: Levels of the second blocking variable. (every trt must occur in every row and every column)

Text

Description automatically generated with medium confidenceAdvantages of LSD: **(1)** When the EU's are heterogeneous due to TWO identifiable sources of variation, LSD is more efficient than RCBD or CRD. **(2)** There is greater sensitivity in the F-test for trt effect in an LSD due to a reduction in SSE. However, the reduction in SSE must be large enough to compensate for the corresponding reduction in the df for MSE. **(3)** A straightforward analysis is available. **(4)** LSD is easy to implement. **(5)** It is possible to combine LSD's of the same size. This is very important when t is small which results in a small value for df of MSE

Disadvantages of LSD: **(1)** The number of levels of the two blocking variables must equal the number of trts. **(2)** When t is small, the df for MSE are small and hence the power of the F-test is relatively low. **(3)** When there are non-additive effects, e.g., the row and column factors interact with the trt effect, the LSD is not appropriate.

* Model: ;

*Relative Efficiency of LSD*: **(1)** RE of LSD to RCBD with rows as our blocks: for cols as blocks use

**(3)** Relative Efficiency of LSD to CRD:

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Description automatically generated*Extensions to the Standard LSD*: Repeat blocks Repeat 1 Blocking Factor New blocking factors in each square

***Balanced Incomplete Block Design (BIBD)*:**

;There are a number of restrictions that must be satisfied in a BIBD:

* **Table

  Description automatically generated(1)** **(2)** **(3)** **(4)**

*Relative Efficiency of BIBD*: BIBD is more precise than RCBD if

Note: In computing SS's we need to account for the fact that not all trts appear in all blocks. Thus, trts are

Adjusted for the effect of the specific blocks in which they appear.

is the sum of the Block Totals for all blocks in which the ith trt appears. Adj. ith trt total

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Chart

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***Split Plot Designs:*** A split-plot design is essentially two experiments superimposed on each other. One experiment has the whole plot factor applied to the larger EU's and the other experiment has the subplot factor applied to the smaller EUS. That is, the Whole Plot factor levels ae assigned to the whole plots in a RCBD. Each whole plot is then subdivided into b subunits and the levels of subplot factor are assigned to the subunits as in a CRD.

* Model: with i=1,…,a; j=1,…,b; k = 1,…,r (# of blocks)
* – the ith whole plot trt effect with ;  **–** the jth split plot trt effect with
* **–** the interaction between the WP trt and SP trt with
* **–** the block effect with ;  **–** the WP error term (Block\* TRT) with
* **–** the SP error term with and all independent

Text

Description automatically generated*Comparisons of Treatment Means*:

* WP Trt Comparisons: with
* SP Trt Comparisons: with
* SP Trt Comparisons at Fixed Levels of WP Trt:
* WP Trt Comps at Fixed Levels of SP Trt: with
* Comp WP Trt (i) at SP Trt (j) to WP Trt (h) at SP Trt (k):
* To estimate the ith WP Trt Mean: with
* To estimate the jth SP Trt Mean: with
* To estimate the ijth trt Mean: with

**Text

Description automatically generated***Completely Randomized Split-Plot Design*: Model: with

* **(1)**  – the ith whole plot trt effect with ; **(2)**  **–** the jth split plot trt effect with ;
* **(3) –** the interaction between the WP trt and SP trt with
* **(4) –** the WP error term (Rep(A)) with
* **(5) –** the SP error term with

*Randomized Complete Block Split-Split-Plot Design*: When we have 3-factors, A-assigned to WP EU's; B-assigned to SP EU's & C-assigned to SSP EU's. A subdivision of the subplots is required with all levels of Factor C randomly assigned to these new subdivisions. There are r blocks containing r Whole Plot EU's each.

* Table

  Description automatically generatedModel: with
* **(1)**  – the ith whole plot trt effect with ; **(2)**  **–** the jth split plot trt effect with ;
* **(3) –** the kth split-split plot trt effect with
* **–** interaction btwn WP and SP trt
* **–** interaction btwn WP and SSP Trt
* **–** interaction btwn SP and SSP Trt
* **–** interaction btwn WP, SP and SSP Trt
* **–** the block effect ; – whole plot error term
* – the SP error term; – SSP error term

***Strip-Plot Design*:** Occurs when the subunit trts occur in a strip across the whole-plot units. The levels of Factor A are randomly assigned to the blots in a RCBD. The plots for Factor B are constructed in the same manner but are laid out perpendicular to the plots for Factor A. The levels of Factor B are then randomly assigned to this second array of plots across the same block. The Strip-plot design has three sizes for EU's where the units for the main effects of Factors A and B are equivalent to WPs but each with a different orientation. The EU's for the A\*B interaction effect is a subplot where there is an interaction of the two WPs for the respective levels of Factors A and B. Consequently, there are three experimental error terms used in the AOV table to test for main effects and the interaction.

* Model: ; where we have r blocks, a levels of factor A and b levels of factor b.
* **Chart

  Description automatically generated with medium confidence(1)**  – the ith WP A trt effect with ; **(2)**  **–** the jth WP B trt effect with ;
* **(3)**  **–** interaction btwn WP and SP trt; **(4)**  **–** the kth block effect, k = 1, …, r
* **(5)** – WP error term for Factor A; **(6)** – WP error term for factor B
* **(7)**  – interaction error term

Table

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H.O.10 Calculations of Estimated Errors of Difference in Marginal and Trt Means: Model:

(1) Compute the estimated SE of the differences in the means for M1 and M2: with

(1a) Tukey HSD for CI: HSD =

(2) Compute the estimated standard error of the differences in the mean speeds: with

Practice Final Multiple-Choice Questions:

1.) Consider a design with equal replication of t treatments in a completely randomized experiment. An examination of the residuals yielded a p-value = .3476 from the Shapiro-Wilks test. What can you conclude about the model conditions?

* C-normal distribution of the residuals does not appear to be violated

2.) A RCBD with three factors: F1-fixed, F2-random, F3-fixed, was conducted. The experimenter obtained the following results from the AOV F-tests: F1 ∗ F2 ∗ F3 is not significant, F1 ∗ F2- significant, F1 ∗ F3-not significant, F2 ∗ F3-significant, and F1, F2, F3 are all significant. She then decides to determine if there are pairwise differences in the levels of F1. Which of the following would be the most appropriate approach to answering her questions.

* B. Tukey’s HSD applied to the levels of F1 averaged over all combinations of (F2, F3).

3.) A covariate was measured along with the responses in a completely randomized design with a single factor having 5 levels. The p-value from the AOV reveals significant evidence that the slopes of the 5 treatment lines are different. A comparison of the 5 treatments

* E. could be made using Tukey’s HSD on the adjusted treatment means at specified values of the covariate.

4.) An entomologist designs an experiment to evaluate the effectiveness of five Dose levels of a pesticide to control fire ants. She randomly selects 100 1-acre plots of land and randomly assigns 20 plots to each dose level. Next, she randomly selects 15 fire ant hills in each plot and records the weight, W, of fire ants killed after two weeks of treatment. The scientist runs the following code in SAS to analyze her data: PROC GLM; CLASS DOSE PLOT; MODEL W = DOSE PLOT(DOSE); RANDOM PLOT(DOSE)/TEST; LSMEANS DOSE/PDIFF ADJUST=TUKEY;

She then uses the output from LSMEANS to group the five Doses according to the mean weight of fire ants killed. The conclusions reached using the SAS output will be incorrect because:

* C-the calculation of SE(µ) is incorrect, SAS only considers σ^2(e) and not σ^2(PLOT(DOSE)) in the calculation.

5.) The response variable yij is observed in a RCBD experiment with five treatments and ten blocks. The researcher fits the model and conducts a residual analysis. The normal probability plot indicates a very right skewed distribution for the residuals. The transformation is suggested by Box-Cox procedure. What would be the most easily interpreted analysis of this data?

* B. Run the Friedman test even though the residuals are very right skewed.

6.) An experiment was conducted as a randomized complete block (RCBD) with 10 blocks and a factorial treatment structure, Factor A with 3 levels and Factor B with 4 levels. The homogeneity of variances condition can be evaluated by:

* E. none of the above (options were A-applying the B-F-L test to the 12 trt vars b/c the data is from 12 populations; B-a box plot of the 120 residuals; C- it is not necessary to have equal variances in a RCBD b/c the heterogeneity in the EU's has been controlled by blocking; D- it is not necessary to have equal variances because with 120 observations, the CLT eliminates the need for equal vars.

7.) A veterinarian wants to investigate t = 10 treatments for controlling heartworms in puppies. Her consulting statistician determines that she will need r = 9 replications per treatment. There is enormous variation in the effectiveness of the treatment so the veterinarian wants to use groups of homogeneous puppies and decides to use litters of puppies as her blocking variable. Most litters contain fewer than 10 puppies so she decides to use a BIBD, with at most 9 puppies per litter. Which of the following combinations of b litters and k puppies per litter would yield the most effective design?

* A. b = 10 and k = 9 (Has the most EU's per trt) (also gave us the largest df for SSE)

8.) An experiment was conducted as a CRD with 6 reps of the 4 levels of a single factor F1. There were measurements taken on each of the 24 experimental units (EU) at time points t1, t2, t3, t4, t5. The analysis of the data was conducted as a CRD split-plot design with F1 as the whole plot treatment and Time of measurement as the split-plot treatment. The p-values from the F-tests for the main effect of Time and the interaction between Time and F1 are only approximations to the true p-values because

* D. the 5 measurements on each EU are not independent.

9.) In a RCBD with 5 blocks and a factorial treatment structure consisting of a qualitative factor F1 at 2 levels and a quantitative factor F2 at 4 levels, the researcher wants to know if the linear trend in the mean responses across the levels of F2 are different for the two levels of F1. Which of the following contrasts would address this question?

* C-;
* From table XI, the coefficients are (-3,-1,1,3) and we want the difference in the contrasts for the 2 levels of F1

10.) A RCBD experiment was run with 3 blocks, 25 EU’s were randomly assigned to each of the 6 levels of a treatment factor, and each EU was measured at 5 specified locations on the EU. Let be the measurement from Lth EU receiving treatment j in block i at location k on the EU.

with

Which one of the follow statements best describes the correlation structure of the random variables in the model?

* B - are independent, are independent and are correlated

11.) In a crossover design evaluating 5 treatments, there may be a strong positive correlation between the 5 responses from the same experimental unit. You recalled that the actual power of the AOV F-test will now be greater than the power of the AOV F-test when the observations are independent. However, the negative impact of positive correlation on the F-test is:

* A. the probability of a Type I Error will be higher than expected under no correlation

12.) A study of the interaction between two factors, Factor A with 4 fixed levels and Factor B with 2 fixed levels, was designed with 5 experimental units randomly assigned to each of the treatments. The FDA requires a power of at least .90 for an α=.01 test whenever there is one or more pairs of treatments having a difference of at least 6 units in their mean responses. From previous studies, it was determined that the variation in responses is approximately . Which one of the following is the closest approximation to the power of the test? Show your calculations.

* D-0.70< Power ≤ 0.90. and