1. The tensile strength of Portland cement is being studied. Four different mixing techniques can be used economically. The following data have been collected:

Table 1:

Mixing technique	Tensile Strength (lb/in^2)			
1	3129	3000	2865	2890
2	3200	3300	2975	3150
3	2800	2900	2985	3050
4	2600	2700	2600	2765

You are also provided with software output which you should use to answer the following:

   (a) Based only on the Fisher (individual) confidence intervals for pairwise differences, do you think Treatments 2 and 3 are significantly different?

   (b) Based only on the Tukey C.I.s, do you think Treatments 2 and 3 are significantly different?

   (c) Do the Tukey and Fisher (individual) confidence intervals reach the same conclusion about statistical significance of the six pairwise differences? If not, provide an explanation.

   (d) Comment on the residual plots. Are the usual one-way ANOVA assumptions met?

2. In a quality control study, random samples of 4 items from each of 3 vendors chosen at random from a large population of vendors, were measured for quality. Complete the ANOVA table and use it to answer the following questions.

Source	SS	Df	MS	EMS
Treatment (Between Vendors)	665.2			$\sigma^2 + 4\sigma^2_{vendor}$
Error (Within Vendors)	543.5			σ^2
Total				

(a) Find estimates of the variance components.

(b) Estimate the intra-class correlation coefficient with a 95% confidence interval. Interpret your interval estimate.

3. The school superintendent is concerned about the development of technology skills in middle school. Since there are 3 middle schools in his district, all of which go about this instruction differently, he decided to assess if there were any differences across schools. He first compiled a long list of "tech skills" and randomly selected 5 to be used in his study. He then randomly selected 20 students from each school and assigned each to one of the five tasks so that there were 4 students per task per school. Each student then performed the skill and a score between 0 and 100 was assigned.

   (a) If a two-way ANOVA is to be used for the analysis, should it be treated as a fixed effects, random effects, or mixed effects model? Explain.

   (b) Complete the following ANOVA table and estimate all variance components.

Source	Sum Sq	Df	Mean Sq	F
School	-----	-----	110.00	-----
Skill	-----	-----	-----	1.09
Interactions	176.00	-----	-----	-----
Errors	450.00	-----	-----	

4. Burdick and Graybill (1992, pp. 11-12) described a quality control experiment designed to study the sources of variability in the length of window screens. It is desired to determine the contribution of the variability in the final product that is due to operators, machines, and the operator $\times$ machine interaction.

   Three operators and four machines are randomly selected from the available operators and machines in the company and each operator

makes two screens on each of the selected machines.

(a) This is a two-way crossed classification. For each of the two factors, indicate if it is appropriate to treat it as fixed or random.

(b) The mathematical notation for this model is

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$$

for $i = 1, 2, 3, j = 1, 2, 3, 4$ and $k = 1, 2$ Based on your answer to part (a) above, write down the usual assumptions on the terms α_i, β_j, $(\alpha\beta)_{ij}$ and ϵ_{ijk}.

(c) Use the ANOVA table below to provide estimates of all the components of variance.

Source	SS	DF	MS
Operator	0.1425		
Machine	0.7112		
Interaction	4.1975		
Error	3.7750		
Total	8.8262		

5. Ostle (1952) discussed the results of an analysis of variance of a three-factor factorial design. The experiment consisted of determining soluble matter in four extract solutions by pippetting in duplicate 25,50, and 100 ml volumes of solution into dishes. The solution was evaporated and weighed for residues. The experiment was replicated by repeating it on three days. The researcher is interested in only the four extracts and only the three volumes used in the experiment. However, the days are considered to be a random sample of days.

(a) Write down a statistical model for this experiment and explain all terms in your model. State all assumptions clearly.

(b) Provide an ANOVA table including all sources of variation and their degrees of freedom. For each source in your ANOVA table, indicate if it is a fixed or a random effect.