In questions 1-4, please circle the correct answer.

1. (4) A factor in a statistical experiment is called a random effect if
   (a) randomization is used to assign experimental units to factor levels.
   (b) the experiment involves three or more factors.
   (c) the factor levels in the experiment are a random sample from a population of levels.
   (d) the distribution of the response variable is not normal.
   (e) it causes the statistician analyzing the experiment to experience unpredictable bouts of nausea.

2. (4) Pearson's correlation coefficient for a set of observations $(x_1, y_1), \ldots, (x_n, y_n)$ is
   (a) near 1 or -1 in all cases where the $x$ and $y$ variables are very strongly related.
   (b) usually a more reliable measure of association than $R^2$ in a regression analysis.
   (c) a measure of the linear relationship between $x$ and $y$.
   (d) all of the above.
   (e) never mentioned in polite company.

3. (4) Probability sampling is usually considered to be preferable to judgement sampling because
   (a) the former method allows an objective assessment of the accuracy of inferences while the latter does not.
   (b) the former method necessarily leads to more accurate estimates than does the latter.
   (c) a frame is not required in probability sampling.
   (d) the latter method requires that the population be stratified.
   (e) drawing numbers out of a hat is a statistician's raison d'être.

4. (4) Which of the following is the condition under which stratified sampling is better than simple random sampling for purposes of estimating the population mean?
   (a) The strata means are all the same.
   (b) The variability within strata is very large.
   (c) The variability within strata is very small.
   (d) The strata means are at least somewhat different.
   (e) The moon is in the Seventh House and Jupiter aligns with Mars.
5. (16 points) A study was carried out to investigate association between smoking and coronary heart disease (CHD). Autopsy records for a sample of 182 cases of sudden and unexpected death were examined. Each victim was classified according to smoking habits (nonsmoker, less than 20 cigarettes per day, 20 or more cigarettes per day) and cause of death (CHD, not CHD). The following counts were recorded:

<table>
<thead>
<tr>
<th></th>
<th>Not CHD</th>
<th>CHD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonsmoker</td>
<td>81</td>
<td>3</td>
<td>84</td>
</tr>
<tr>
<td>Less than 20</td>
<td>29</td>
<td>8</td>
<td>37</td>
</tr>
<tr>
<td>20 or more</td>
<td>43</td>
<td>18</td>
<td>61</td>
</tr>
<tr>
<td>Total</td>
<td>153</td>
<td>29</td>
<td>182</td>
</tr>
</tbody>
</table>

(a) (12) Is there any evidence of an association between smoking and CHD?

\[
X^2 = \frac{(81-70.62)^2}{70.62} + \frac{(3-13.38)^2}{13.38} + \frac{(29-31.10)^2}{31.10} \\
+ \frac{(8-5.90)^2}{5.90} + \frac{(43-51.28)^2}{51.28} + \frac{(18-9.72)^2}{9.72} = 18.86
\]

This is larger than \( X^2_{a,.05} = 5.991 \), and so we conclude that smoking and CHD are related.

(b) (4) Is your test in (a) a test for homogeneity of proportions or a test of independence of traits? Justify your answer.

**It is a test of independence of traits since we have a single sample of 182 cases, and we cross-classify each case according to smoking status and CHD.**
6. (16 points) An experiment was conducted to assess the effect of caffeine on the endurance of athletes. Nine well-conditioned cyclists were available for the study, and four caffeine dosages were considered: 0, 5, 9 and 13 mg. The experiment was conducted over four days and each cyclist ended up receiving all four caffeine doses, one dose per day. The order in which the doses were administered was randomly determined for each cyclist. The response variable was number of minutes of cycling between receiving the caffeine and exhaustion setting in. An analysis of variance table is given below and some SPSS output for the data are in the accompanying handout.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caffeine</td>
<td>933.122</td>
<td>3</td>
<td>311.041</td>
<td>5.917</td>
<td>0.004</td>
</tr>
<tr>
<td>Cyclists</td>
<td>5557.994</td>
<td>8</td>
<td>694.749</td>
<td>13.216</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>1261.657</td>
<td>24</td>
<td>52.569</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7752.773</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) (10) Is there evidence that the mean time to exhaustion is not the same for all four caffeine doses? If so, determine the nature of the differences.

Since the P-value for caffeine is 0.004, we conclude that average time to exhaustion is not the same for all four doses. Tukey's procedure shows that average time to exhaustion is less for no caffeine than for any other dose.

There is no sig. diff. between the three actual caffeine doses.

(b) (6) Estimate the efficiency of this randomized block design relative to a completely randomized design, and interpret the number you obtain.

\[
RE = \frac{8(694.749) + 9(3)(52.569)}{35(52.569)} = 3.79
\]

About 4 times as many cyclists would have been required in order for a CRD to yield the same efficiency in estimating a treatment mean.
7. (18) A physiologist investigated the relationship between the physical characteristics of boys and their maximal oxygen uptake \((y\) in ml of oxygen per kg of body weight). The independent variables were age \((x_1\) in years), height \((x_2\) in cm), weight \((x_3\) in kg), and chest depth \((x_4\) in cm). Use the accompanying SPSS output to help you answer (a)-(c).

(a) (7) The physiologist likes the simplicity of the model using just age and height. Does the model involving all four independent variables improve significantly upon the one with just age and height?

\[
F = \frac{(0.206 - 0.200)^2}{0.01} = 3 \quad F_{2, 5, 0.05} = 5.79
\]

No, the more complicated model does not improve significantly upon the simpler one.

(b) (4) Consider now the model containing all four independent variables. It seems reasonable to assume that the weight of a child should be positively correlated to lung volume and hence to maximal oxygen uptake. But we find that \(\hat{\beta}_3\), the estimated coefficient for weight, \(x_3\), is negative. Give an explanation for this result.

This is probably due to collinearity. The VIF for \(\hat{\beta}_3\) is about 5, meaning the var. of \(\hat{\beta}_3\) is 5 times larger than it would be in the absence of collinearity.

(c) (7) By means of an interval in which you have 95\% confidence, predict the maximal oxygen uptake of Joey (the physiologist's son), for whom \(x_1 = 9\), \(x_2 = 130\), \(x_3 = 25.9\) and \(x_4 = 13.6\). Use the model with all four independent variables and the fact that the estimated standard error of \(\hat{\beta}_0 + \hat{\beta}_1(9) + \hat{\beta}_2(130) + \hat{\beta}_3(25.9) + \hat{\beta}_4(13.6)\) is 0.03324.

\[
\hat{\mu}_x = 1.5367 \quad 1.5367 \pm 2.571 \sqrt{0.001 + (0.03324)^2} = 1.5367 \pm 0.118, \quad \text{or} \quad (1.419, 1.655)
\]
8. (18 points) A soft drink distributor is studying the effectiveness of delivery methods. Three different types of hand trucks (call them A, B and C) have been developed, and an experiment is performed in the company’s methods engineering laboratory. The response is the delivery time in minutes (y). Delivery time is strongly related to case volume delivered (x), and hence case volume is treated as a covariate. Each type of hand truck is used four times, and the resulting data are shown below, with the type of truck being the plotting character:

![Graph showing delivery time vs. case volume for hand trucks A, B, and C.]

In the accompanying SPSS output, the variables $x_2$, $x_3$, $x_4$, and $x_5$ are defined as follows:

$$x_2 = \begin{cases} 
1, & \text{hand truck A is used} \\
0, & \text{otherwise}
\end{cases}, \quad x_3 = \begin{cases} 
1, & \text{hand truck B is used} \\
0, & \text{otherwise}
\end{cases},$$

$x_4 = x_2$ and $x_5 = x_3$.

Use the SPSS output to conduct a complete analysis of covariance to see if the type of hand truck affects delivery time.

First test that slopes are same.

$$F = \frac{(1253.251 - 1243.719)^2}{5.403} = 0.882 < F_{2, 6.05} = 5.14$$

Cannot conclude slopes are diff. Now test for a diff. in intercepts assuming slopes are same.

$$F = \frac{(1243.719 - 1232.072)^2}{5.243} = 1.11 < F_{2, 8.05} = 4.46$$

Cannot conclude any diff. in mean delivery time for the three types of hand trucks.