

Stat 4473 – Data Analysis
ANOVA Homework

1. Productivity improvement. An economist compiled data on productivity improvements last year for a sample of firms producing electronic computing equipment. He wishes to investigate whether research and development expenditures affect productivity improvement. The firms were classified according to the level of their average expenditures for research and development in the past three years (low, moderate, high). The results of the study follow (productivity improvement is measured on a scale from 0 to 100).

| | | <i>J</i> | | | | | | | | | | | |
|----------|----------|----------|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>i</i> | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Low | 7.6 | 8.2 | 6.8 | 5.8 | 6.9 | 6.6 | 6.3 | 7.7 | 6.0 | | | |
| 2 | Moderate | 6.7 | 8.1 | 9.4 | 8.6 | 7.8 | 7.7 | 8.9 | 7.9 | 8.3 | 8.7 | 7.1 | 8.4 |
| 3 | High | 8.5 | 9.7 | 10.1 | 7.8 | 9.6 | 9.5 | | | | | | |

2. Cash offers. A consumer organization studied the effect of age of automobile owner on size of cash offer for a used car by utilizing 12 persons in each of three age groups (young, middle, elderly) who acted as the owner of a used car. A medium price, six-year-old car was selected for the experiment, and the "owners" solicited cash offers for this car from 36 dealers selected at random from the dealers in the region. Randomization was used in assigning the dealers to the "owners." The offers (in hundred dollars) follow.

| | | <i>J</i> | | | | | | | | | | | |
|----------|---------|----------|----|----|----|----|----|----|----|----|----|----|----|
| <i>i</i> | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Young | 23 | 25 | 21 | 22 | 21 | 22 | 20 | 23 | 19 | 22 | 19 | 21 |
| 2 | Middle | 28 | 27 | 27 | 29 | 26 | 29 | 27 | 30 | 28 | 27 | 26 | 29 |
| 3 | Elderly | 23 | 20 | 25 | 21 | 22 | 23 | 21 | 20 | 19 | 20 | 22 | 21 |

3. Filling machines. A company uses six filling machines of the same make and model to place detergent into cartons that show a label weight of 32 ounces. The production manager has complained that the six machines do not place the same amount of fill into the cartons. A consultant requested that 20 filled cartons be selected randomly from each of the six machines and the content of each carton carefully weighed. The observations (stated for convenience as deviations from 32.00 ounces) follow.

| | | <i>j</i> | | | | | | | |
|----------|--|----------|------|-----|-----|-----|------|------|--|
| <i>i</i> | | 1 | 2 | 3 | ... | 18 | 19 | 20 | |
| 1 | | -.14 | .20 | .07 | ... | .07 | -.01 | -.19 | |
| 2 | | .46 | .11 | .12 | ... | .02 | .11 | .12 | |
| 3 | | .21 | .78 | .32 | ... | .50 | .20 | .61 | |
| 4 | | .49 | .58 | .52 | ... | .42 | .45 | .20 | |
| 5 | | -.19 | .27 | .06 | ... | .14 | .35 | -.18 | |
| 6 | | .05 | -.05 | .28 | ... | .35 | -.09 | .05 | |

I'll e-mail you the complete data set.

4. Weight loss. An experiment was conducted to compare the effectiveness of five different weight-reducing agents. A random sample of 50 males was randomly divided into five equal groups with preparation A assigned to the first group, B to the second, and so on. Each person in the experiment was given a pre-study physical and told how many pounds over weight he was. A comparison of the mean number of pounds overweight for the groups showed no significant differences. The study program was then begun with each group taking the prescribed preparation for a fixed period of time. At the end of the study period, weight losses were recorded. The data are given here.

| <i>I</i> | <i>J</i> | | | | | | | | | |
|----------|----------|------|------|------|------|------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| A | 12.4 | 10.7 | 11.9 | 11.0 | 12.4 | 12.3 | 13.0 | 12.5 | 11.2 | 13.1 |
| B | 9.1 | 11.5 | 11.3 | 9.7 | 13.2 | 10.7 | 10.6 | 11.3 | 11.1 | 11.7 |
| C | 8.5 | 11.6 | 10.2 | 10.9 | 9.0 | 9.6 | 9.9 | 11.3 | 10.5 | 11.2 |
| D | 8.7 | 9.3 | 8.2 | 8.3 | 9.0 | 9.4 | 9.2 | 12.2 | 8.5 | 9.9 |
| E | 12.7 | 13.2 | 11.8 | 11.9 | 12.2 | 11.2 | 13.7 | 11.8 | 11.5 | 11.7 |

5. In a project for a botany class, 15 sunflower seeds were randomly assigned to and planted in pots whose soil had been subjected to one of three fertilizer treatments. Twelve of the seeds germinated, and the table below shows the height of each plant (in cm) 2 weeks after germination. Are there significant differences in heights among treatments?

| <i>i</i> | | <i>J</i> | | | | |
|----------|-------------|----------|----|----|----|----|
| | | 1 | 2 | 3 | 4 | 5 |
| 1 | Treatment 1 | 23 | 27 | 32 | 34 | |
| 2 | Treatment 2 | 26 | 28 | 33 | 35 | 38 |
| 3 | Treatment 3 | 25 | 26 | 33 | | |

6. An instructor in a second-term calculus course wishes to determine whether the year in college has any effect on the performance of his students on their final exam. The table below lists the exam grade (out of 150) for students categorized by year. Are there significant differences in performance among years?

| <i>i</i> | | <i>J</i> | | | | | | | | |
|----------|------------|----------|-----|-----|-----|-----|-----|-----|-----|-----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | First year | 122 | 111 | 104 | 118 | 113 | 98 | 129 | 111 | 127 |
| 2 | Sophomore | 117 | 97 | 113 | 123 | 130 | | | | |
| 3 | Junior | 72 | 91 | 71 | 72 | 96 | 121 | | | |

7. Workers at a tree farm decided to test the efficacy of three fertilizer mixtures on the growth of Norway maple seedlings, *Acer platanoides*. The table below contains the heights of seedlings (in feet) for the three fertilizer treatments. Determine if there are significant differences in the heights among the three treatments.

| | | <i>J</i> | | | | | | | | | |
|----------|---|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>i</i> | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | A | 2.0 | 2.1 | 2.4 | 2.8 | 2.9 | 3.1 | 3.2 | 3.7 | 3.8 | 4.1 |
| 2 | B | 2.3 | 2.9 | 1.5 | 1.2 | 1.9 | 1.9 | 3.4 | 2.1 | 2.6 | 2.4 |
| 3 | C | 3.1 | 1.5 | 2.2 | 2.9 | 1.7 | 2.1 | 2.8 | 1.5 | 2.8 | 2.2 |

- ◆ For each problem, perform the one-way ANOVA F-test and draw conclusions. Your write-up should include statements of the null and alternative hypotheses, the test statistic and its distribution, the value of the observed test statistic, the formula for the p-value and the p-value itself, and your conclusion. Don't forget to check the assumptions, and report those checks.
- ◆ When appropriate, perform Tukey multiple comparisons (by way of Tukey confidence intervals) and interpret.