

## IE 361 Lab#9/ A One-Way Analysis of a Paper Helicopter Experiment

\_\_\_\_\_  
(Name)

In this lab, we're going to do some experimenting with different "paper helicopter designs." The mechanics of our testing will be exactly as in Lab #8. That is, when your helicopters have been made, go out into the hall and use the yardstick to measure up 6 ft from the floor and attach a piece of string to the wall at that height with a piece of masking tape. Extend the string out perpendicular from the wall to establish a launch location. Assign one team member to act as the timer. This person will tell the person launching whether the string appears to be parallel to the floor, use the stopwatch, give the "5,4,3,2,1,launch" command sequence, and be responsible for announcing the flight time for each launch. Assign another team member to do the data recording.

We are going to make and test helicopters of 4 different types. These are:

**Type 1 -- "regular tail" and 1 paper clip**

**Type 2 -- "regular tail" and 2 paper clips**

**Type 3 -- "short tail" and 1 paper clip**

**Type 4 -- "short tail" and 2 paper clips**

Here "short tail" is going to mean folding the part of the helicopter that hangs down "in half" (back up toward the rotors so that it extends only half as far below the body of the helicopter as it does before folding). We're going to make and test 3 helicopters of each type, for purposes of trying to see if there are discernable differences between flight times for the 4 designs. Make these helicopters and write on them serial numbers as follows:

**Type 1:** 01, 02, 03    **Type 2:** 04, 05, 06    **Type 3:** 07, 08, 09    **Type 4:** 10, 11, 12

For our basic "measurements" on a helicopter here, we're going to take averages of 5 consecutive drop times. In an attempt to in some sense physically "average" between the 4 helicopter types the effects on drop time of any unforeseen changes in conditions in the hall during the testing, we'll NOT do the testing in a systematic order as regards helicopter type. Instead we'll test the helicopters in a randomly determined order. Your instructor "randomly" shuffled the serial numbers above and got the testing order

06,09,03,02,08,11,05,10,12,04,01,07

This is the order indicated on the data collection sheet attached as the last page of this lab.

Make and record 5 consecutive drop times for your 12 helicopters on the data collection form. Then collect below the 3 "observations"  $y$  for each of the 4 types. (You should have a single number gotten as an average of 5 drop times FOR EACH HELICOPTER ... 3 per helicopter type.)

Type, $i$	$y_{ij}$ 's			$\bar{y}_i$	$s_i$
1					
2					
3					
4					

Compute the sample means and sample standard deviations for the 4 different helicopter designs and put them in the table above.

a) Compute a single estimate of the standard deviation of  $y$  for helicopters of any fixed design. Report it below (and include appropriate units).

$$s_{\text{pooled}} = \underline{\hspace{2cm}}$$

b) What are appropriate degrees of freedom for your estimate in a)? Use your answer to a) and make 95% two-sided confidence limits for the standard deviation  $y$  for helicopters of any fixed design.

$$\nu = \underline{\hspace{2cm}} \quad \text{confidence limits: } \underline{\hspace{4cm}}$$

c) One might use the sample means  $\bar{y}_i$  to represent the mean flight times of helicopters of the 4 different types. What is a sensible margin of error or uncertainty to associate with any of these values? Base your answer on 95% confidence limits for a single mean ( $\mu_i$ ) namely

$$\bar{y}_i \pm t s_{\text{pooled}} / \sqrt{n_i} .$$

margin of error associated with  $\bar{y}_i$  :  $\underline{\hspace{2cm}}$

d) Both the quantities  $L = \mu_2 - \mu_1$  and  $L = \mu_4 - \mu_3$  are measures of the effect on mean flight time of adding a second paper clip to a helicopter design. Make 95% confidence limits for these two quantities (TWO different intervals are to be made). (Here where  $L = \mu_i - \mu_{i'}$ , the basic formula for estimating an  $L$  reduces to  $(\bar{y}_i - \bar{y}_{i'}) \pm ts_{\text{pooled}} \sqrt{(1/n_1) + (1/n_2)}$ .)

limits for  $\mu_2 - \mu_1$ : \_\_\_\_\_

limits for  $\mu_4 - \mu_3$ : \_\_\_\_\_

e) The quantity  $L = \frac{1}{2}(\mu_2 - \mu_1) + \frac{1}{2}(\mu_4 - \mu_3)$  could be seen as a single overall measure of the effect on mean flight time of adding a second paper clip to a design. Make 95% two-sided confidence limits for this quantity using the formula  $\hat{L} \pm ts_{\text{pooled}} \sqrt{(c_1^2/n_1) + \dots + (c_r^2/n_r)}$ .

limits for  $L$ : \_\_\_\_\_

## "Statistical Tolerancing"

Module 19 and Section 5.4 of *SQAME* cover the topic of "statistical tolerancing." As practice with that material consider Problem 5.37 of *SQAME*.

a) Show the calculus and arithmetic necessary to verify that the value of  $\partial\lambda / \partial D = -.249$  as indicated in the table in the problem.

b) Do the problem as written on pages 264-265 of *SQAME*.

<b>Helicopter Serial #</b>	<b>Time 1</b>	<b>Time 2</b>	<b>Time 3</b>	<b>Time 4</b>	<b>Time 5</b>	<b>y = helicopter average time</b>	<b>Type</b>
<b>06</b>							<b>2</b>
<b>09</b>							<b>3</b>
<b>03</b>							<b>1</b>
<b>02</b>							<b>1</b>
<b>08</b>							<b>3</b>
<b>11</b>							<b>4</b>
<b>05</b>							<b>2</b>
<b>10</b>							<b>4</b>
<b>12</b>							<b>4</b>
<b>04</b>							<b>2</b>
<b>01</b>							<b>1</b>
<b>07</b>							<b>3</b>