ISE 2211 • Exam VII • 3 December 2021 NAME SOLUTION

It is well-established that oxide thickness is directly connected to maximum working voltage in the design of aluminum electrolytic capacitors. Engineering would like to know if working voltage is *significantly* affected at the four specific levels listed below. Use Analysis of Variance (ANOVA) to test the null hypothesis that the treatment mean working voltages are equal at the $\alpha = 0.05$ level of significance. Fill in the ANOVA table.

Oxide Thickness (nm)	Maximum Working Voltage (V)					Totals	Averages
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5		
440	319	343	313	291	324	1590	318
480	343	367	358	332	326	1726	345.2
520	339	341	326	350	343	1699	339.8
560	379	386	390	376	412	1943	388.6
						6958	347.9

$$\sum_{i=1}^{a}\sum_{j=1}^{n} y_{ij}^2 = 2437522$$

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	f_0
Treatments	13117	3	4372.3	18.82
Error	3716.8	16	232.3	-
Total	16833.8	19	-	-

(+1) entered into table correctly

(+2) $SS_T = 2437522 - \frac{6958^2}{4\times5} = 16833.8$ $4\cdot5-1 = 19$ d.o.f.

(+2) $SS_{Tr} = \frac{1590^2 + 1726^2 + 1699^2 + 1943^2}{5} - \frac{6958^2}{4\times5}$

$= 13117$ $4-1 = 3$ d.o.f.

(+2) $SS_E = 16833.8 - 13117 = 3716.8$ $4(5-1) = 16$ d.o.f.

(+2) $MS_{Tr} = \frac{13117}{3} = 4372.3$

$MS_E = \frac{3716.8}{16} = 232.3$

$f_0 = \frac{4372.3}{232.3} = 18.82$ (+1)

$f_{crit.} = f_{.05,3,16} = 3.24$ (+1)

$f_0 > f_{crit}$; reject H_0 (+2) ... at least one pair shows sig. difference (+2)

Write a 95% confidence interval on working voltage at the 440-nm thickness level.

$$t_{\alpha/2,\,9(n-1)} = t_{.025,16} = 2.120 \text{ (table)}$$

(+2)

$$\mu_1: \quad 318 \pm 2.120\sqrt{\frac{232.3}{5}}$$

$$303.5 < \mu_1 < 332.5 \quad (V)$$

(+2) (+1)

Use Fisher's Least Significant Difference to determine which, if any, pairs of thicknesses show significant difference at $\alpha = 0.05$.

$$LSD = t_{.025,16}\sqrt{\frac{2 \cdot 232.3}{5}} = 2.120 \cdot 20.44 = 20.44$$ (+2)

440 vs. 480 : $|318 - 345.2| = 27.2 > LSD$

440 vs. 520 : $|345.2 - 339.8| = 5.4$

520 vs. 560 : $|339.8 - 388.6| = 48.8 > LSD$

440 vs. 520 : $|318 - 339.8| = 21.8 > LSD$

480 vs. 560 : $|345.2 - 388.6| = 43.4 > LSD$

440 vs. 560 : $|318 - 388.6| = 70.6 > LSD$

(+6)

all pairs show significant difference except 480 vs. 520 nm (+1)