**13.1**

**(a)**.

ANOVA: Measurement versus Part, Operator

Factor Type Levels Values

Part random 10 1 2 3 4 5 6 7 8 9 10

Operator random 2 1 2

Analysis of Variance for Measure

Source DF SS MS F P

Part 9 99.017 11.002 18.28 0.000

Operator 1 0.417 0.417 0.69 0.427

Part\*Operator 9 5.417 0.602 0.40 0.927

Error 40 60.000 1.500

Total 59 164.850

Source Variance Error Expected Mean Square for Each Term

component term (using restricted model)

1 Part 1.73333 3 (4) + 3(3) + 6(1)

2 Operator -0.00617 3 (4) + 3(3) + 30(2)

3 Part\*Operator -0.29938 4 (4) + 3(3)

4 Error 1.50000 (4)

**(b).**

**13.17**

**(d).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | F | F | R | R | R |  |
|  | a | b | c | d | n |  |
| Factor | i | j | k | l | h | E(*MS*) |
|  | 0 | b | c | d | n |  |
|  | a | 0 | c | d | n |  |
|  | a | b | 1 | d | n |  |
|  | a | b | c | 1 | n |  |
|  | 0 | 0 | c | d | n |  |
|  | 0 | b | 1 | d | n |  |
|  | 0 | b | c | 1 | n |  |
|  | a | 0 | 1 | d | n |  |
|  | a | 0 | c | 1 | n |  |
|  | a | b | 1 | 1 | n |  |
|  | 0 | 0 | 1 | d | n |  |
|  | 0 | 0 | c | 1 | n |  |
|  | a | 0 | 1 | 1 | n |  |
|  | 0 | b | 1 | 1 | n |  |
|  | 0 | 0 | 1 | 1 | n |  |
|  | 1 | 1 | 1 | 1 | 1 |  |

ANOVA: y versus A, B, C, D

Factor Type Levels Values

A fixed 2 H L

B fixed 2 H L

C random 2 H L

D random 2 H L

Analysis of Variance for y

Source DF SS MS F P

A 1 6.13 6.13 1.96 0.604 x

B 1 0.13 0.13 0.04 0.907 x

C 1 1.13 1.13 0.36 0.656

D 1 0.13 0.13 0.04 0.874

A\*B 1 3.13 3.13 0.11 0.796 x

A\*C 1 3.13 3.13 1.00 0.500

A\*D 1 3.13 3.13 1.00 0.500

B\*C 1 3.13 3.13 1.00 0.500

B\*D 1 3.13 3.13 1.00 0.500

C\*D 1 3.13 3.13 0.25 0.622

A\*B\*C 1 3.13 3.13 1.00 0.500

A\*B\*D 1 28.13 28.13 9.00 0.205

A\*C\*D 1 3.13 3.13 0.25 0.622

B\*C\*D 1 3.13 3.13 0.25 0.622

A\*B\*C\*D 1 3.13 3.13 0.25 0.622

Error 16 198.00 12.38

Total 31 264.88

x Not an exact F-test.

Source Variance Error Expected Mean Square for Each Term

component term (using restricted model)

1 A \* (16) + 4(13) + 8(7) + 8(6) + 16Q[1]

2 B \* (16) + 4(14) + 8(9) + 8(8) + 16Q[2]

3 C -0.1250 10 (16) + 8(10) + 16(3)

4 D -0.1875 10 (16) + 8(10) + 16(4)

5 A\*B \* (16) + 2(15) + 4(12) + 4(11) + 8Q[5]

6 A\*C 0.0000 13 (16) + 4(13) + 8(6)

7 A\*D 0.0000 13 (16) + 4(13) + 8(7)

8 B\*C 0.0000 14 (16) + 4(14) + 8(8)

9 B\*D 0.0000 14 (16) + 4(14) + 8(9)

10 C\*D -1.1563 16 (16) + 8(10)

11 A\*B\*C 0.0000 15 (16) + 2(15) + 4(11)

12 A\*B\*D 6.2500 15 (16) + 2(15) + 4(12)

13 A\*C\*D -2.3125 16 (16) + 4(13)

14 B\*C\*D -2.3125 16 (16) + 4(14)

15 A\*B\*C\*D -4.6250 16 (16) + 2(15)

16 Error 12.3750 (16)

\* Synthesized Test.

Error Terms for Synthesized Tests

Source Error DF Error MS Synthesis of Error MS

1 A 0.33 3.13 (6) + (7) - (13)

2 B 0.33 3.13 (8) + (9) - (14)

5A\*B 0.98 28.13 (11) + (12) - (15)

**(e).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | F | F | R | R | R |  |
|  | a | b | c | d | n |  |
| Factor | i | j | k | l | h | E(*MS*) |
|  | 0 | b | c | d | n |  |
|  | a | 0 | c | d | n |  |
|  | a | b | 0 | d | n |  |
|  | a | b | c | 1 | n |  |
|  | 0 | 0 | c | d | n |  |
|  | 0 | b | 0 | d | n |  |
|  | 0 | b | c | 1 | n |  |
|  | a | 0 | 0 | d | n |  |
|  | a | 0 | c | 1 | n |  |
|  | a | b | 0 | 1 | n |  |
|  | 0 | 0 | 0 | d | n |  |
|  | 0 | 0 | c | 1 | n |  |
|  | a | 0 | 0 | 1 | n |  |
|  | 0 | b | 0 | 1 | n |  |
|  | 0 | 0 | 0 | 1 | n |  |
|  | 1 | 1 | 1 | 1 | 1 |  |

ANOVA: y versus A, B, C, D

Factor Type Levels Values

A fixed 2 H L

B fixed 2 H L

C fixed 2 H L

D random 2 H L

Analysis of Variance for y

Source DF SS MS F P

A 1 6.13 6.13 1.96 0.395

B 1 0.13 0.13 0.04 0.874

C 1 1.13 1.13 0.36 0.656

D 1 0.13 0.13 0.01 0.921

A\*B 1 3.13 3.13 0.11 0.795

A\*C 1 3.13 3.13 1.00 0.500

A\*D 1 3.13 3.13 0.25 0.622

B\*C 1 3.13 3.13 1.00 0.500

B\*D 1 3.13 3.13 0.25 0.622

C\*D 1 3.13 3.13 0.25 0.622

A\*B\*C 1 3.13 3.13 1.00 0.500

A\*B\*D 1 28.13 28.13 2.27 0.151

A\*C\*D 1 3.13 3.13 0.25 0.622

B\*C\*D 1 3.13 3.13 0.25 0.622

A\*B\*C\*D 1 3.13 3.13 0.25 0.622

Error 16 198.00 12.38

Total 31 264.88

Source Variance Error Expected Mean Square for Each Term

component term (using restricted model)

1 A 7 (16) + 8(7) + 16Q[1]

2 B 9 (16) + 8(9) + 16Q[2]

3 C 10 (16) + 8(10) + 16Q[3]

4 D -0.7656 16 (16) + 16(4)

5 A\*B 12 (16) + 4(12) + 8Q[5]

6 A\*C 13 (16) + 4(13) + 8Q[6]

7 A\*D -1.1563 16 (16) + 8(7)

8 B\*C 14 (16) + 4(14) + 8Q[8]

9 B\*D -1.1563 16 (16) + 8(9)

10 C\*D -1.1563 16 (16) + 8(10)

11 A\*B\*C 15 (16) + 2(15) + 4Q[11]

12 A\*B\*D 3.9375 16 (16) + 4(12)

13 A\*C\*D -2.3125 16 (16) + 4(13)

14 B\*C\*D -2.3125 16 (16) + 4(14)

15 A\*B\*C\*D -4.6250 16 (16) + 2(15)

16 Error 12.3750 (16)

**14.7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | F | R | R | R |  |
|  | a | b | c | n |  |
| Factor | i | j | k | l | E(*MS*) |
|  | 0 | b | c | n |  |
|  | 1 | 1 | c | n |  |
|  | 1 | 1 | 1 | n |  |
|  | 1 | 1 | 1 | 1 |  |

ANOVA: y versus A, B, C

Factor Type Levels Values

A fixed 2 -1 1

B(A) random 2 -1 1

C(A B) random 2 -1 1

Analysis of Variance for y

Source DF SS MS F P

A 1 0.250 0.250 0.06 0.831

B(A) 2 8.500 4.250 0.35 0.726

C(A B) 4 49.000 12.250 2.13 0.168

Error 8 46.000 5.750

Total 15 103.750

Source Variance Error Expected Mean Square for Each Term

component term (using restricted model)

1 A 2 (4) + 2(3) + 4(2) + 8Q[1]

2 B(A) -2.000 3 (4) + 2(3) + 4(2)

3 C(A B) 3.250 4 (4) + 2(3)

4 Error 5.750 (4)

**14.13**

The linear model is

ANOVA: Yield versus Machine, Power, Station

Factor Type Levels Values

Machine fixed 3 1 2 3

Power fixed 2 1 2

Station(Machine) fixed 3 1 2 3

Analysis of Variance for Yield

Source DF SS MS F P

Machine 2 21.143 10.572 6.46 0.004

Power 1 853.631 853.631 521.80 0.000

Station(Machine) 6 32.583 5.431 3.32 0.011

Machine\*Power 2 0.616 0.308 0.19 0.829

Power\*Station(Machine) 6 28.941 4.824 2.95 0.019

Error 36 58.893 1.636

Total 53 995.808

Source Variance Error Expected Mean Square for Each Term

Component term (using restricted model)

1 Machine 6 (6) + 18Q[1]

2 Power 6 (6) + 27Q[2]

3 Station(Machine) 6 (6) + 6Q[3]

4 Machine\*Power 6 (6) + 9Q[4]

5 Power\*Station(Machine) 6 (6) + 3Q[5]

6 Error 1.636 (6)

**14.14**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | R | F | F | R |  |
|  | 2 | 3 | 3 | 3 |  |
| Factor | i | j | k | l | E(*MS*) |
|  | 1 | 3 | 3 | 3 |  |
|  | 2 | 0 | 3 | 3 |  |
|  | 1 | 0 | 3 | 3 |  |
|  | 2 | 1 | 0 | 3 |  |
|  | 1 | 1 | 0 | 3 |  |
|  | 1 | 1 | 1 | 1 |  |

Factor Type Levels Values

Machine fixed 3 1 2 3

Power random 2 1 2

Station(Machine) fixed 3 1 2 3

Analysis of Variance for Yield

Source DF SS MS F P

Machine 2 21.143 10.572 34.33 0.028

Power 1 853.631 853.631 521.80 0.000

Station(Machine) 6 32.583 5.431 1.13 0.445

Machine\*Power 2 0.616 0.308 0.19 0.829

Power\*Station(Machine) 6 28.941 4.824 2.95 0.019

Error 36 58.893 1.636

Total 53 995.808

Source Variance Error Expected Mean Square for Each Term

Component term (using restricted model)

1 Machine 4 (6) + 9(4) + 18Q[1]

2 Power 31.5554 6 (6) + 27(2)

3 Station(Machine) 5 (6) + 3(5) + 6Q[3]

4 Machine\*Power -0.1476 6 (6) + 9(4)

5 Power\*Station(Machine) 1.0625 6 (6) + 3(5)

6 Error 1.6359 (6)