The conclusions are

(A) $F = 116.08/36.92 = 3.14$, so the treatment is significant at a 5% level.
(B) $F = 116.08/18.56 = 6.29$, so the treatment is significant at a 5% level.
(C) $F = 7.255/9.23 = 0.786$, so the treatment is not significant at a 5% level.
(D) $F = 9.23/7.255 = 1.27$, so the treatment is not significant at a 5% level.

Solution

From the F-distribution table, $F^*_{4,16,0.05} = 3.01$.

$$F = \frac{\text{mean of squares between samples}}{\text{mean of squares within samples}} = \frac{\frac{36.92}{4}}{\frac{116.08}{16}}$$
$$= 1.27$$

The sample effect from treatment is not significant at a 5% level; that is, the fluctuation within the samples is more significant than the differences between samples.

The answer is D.

Problem 13

Defects in the finished surface of furniture are approximately Poisson distributed with a mean of 0.015 defects/m^2. A finished bookshelf board containing 10 m^2 of finished surface is considered defective if it contains more than one defect. If shelves are packaged 50 per box, the probability that a box contains fewer than 2 defective items is most nearly

(A) 0.50
(B) 0.61
(C) 0.82
(D) 0.91

Solution

Let x = the number of defects per board (10 m^2). x is Poisson distributed.

$$P(x) = \frac{\lambda^x e^{-\lambda}}{x!} \quad x = 0, 1, 2, \ldots$$
$$\lambda = \frac{\text{average number of defects}}{\text{board}}$$
$$= \left(\frac{10\ \text{m}^2}{1\ \text{board}}\right)\left(0.015\ \frac{\text{defect}}{\text{m}^2}\right)$$
$$= 0.15\ \text{defects/board}$$

$$P\binom{\text{board}}{\text{defective}} = P(x > 1) = 1 - P(x \le 1)$$
$$= 1 - P(x = 0) - P(x = 1)$$
$$= 1 - \frac{(0.15)^0 e^{-0.15}}{0!} - \frac{(0.15)^1 e^{-0.15}}{1!}$$
$$= 1 - 0.8607 - 0.1291$$
$$= 0.0102$$
$$P\binom{\text{not}}{\text{defective}} = 1 - 0.0102 = 0.9898$$

Let y = number of defects in a box. y follows a binomial distribution.

$$P(y) = \binom{50}{y}(0.0102)^y(0.9898)^{50-y}$$
$$y = 0, 1, 2, \ldots, 50$$
$$P(y < 2) = P(y \le 1) = P(y = 0) + P(y = 1)$$
$$= \binom{50}{0}(0.0102)^0(0.9898)^{50}$$
$$+ \binom{50}{1}(0.0102)^1(0.9898)^{49}$$

= 0.5989 + ~~0.3086~~ 0.00617

= ~~0.9075 (0.91)~~ 0.6051 (0.61)

The answer is ~~D~~. B

Problem 14

A product consists of two parts that are placed end to end. Assume that the dimensions of the length of the parts are approximately normally distributed with the mean and standard deviation shown as follows.

	mean length (in)	standard deviation (in)
part A	2.65	0.12
part B	1.45	0.38

The probability that the combined length is greater than 4.35 in is approximately

(A) 0.20
(B) 0.26
(C) 0.55
(D) 0.90

Solution

Let μ_A = mean length of part A, and let μ_B = mean length of part B.

$$\sigma_A^2 = \text{variance of length of part A}$$
$$\sigma_B^2 = \text{variance of length of part B}$$
$$x_A = \text{length of part A}$$
$$x_B = \text{length of part B}$$
$$t = \text{total length} = x_A + x_B$$

Problem 31

What is the dual of the following problem?

$$\begin{aligned} \text{maximize} \quad & 5x_1 + 3x_2 \\ \text{subject to} \quad & -2x_1 + 2x_2 \le 8 \\ & 3x_1 - 6x_2 \le 10 \\ & x_1,\ x_2 \ge 10 \end{aligned}$$

(A)
$$\begin{aligned} \text{minimize} \quad & 5y_1 + 3y_2 \\ \text{subject to} \quad & -2y_1 - 2y_2 \ge 8 \\ & -3y_1 + 6y_2 \ge 10 \\ & y_1,\ y_2 \ge 0 \end{aligned}$$

(B)
$$\begin{aligned} \text{minimize} \quad & 8y_1 + 10y_2 \\ \text{subject to} \quad & -2y_1 + 3y_2 \ge 5 \\ & 2y_1 + 6y_2 \ge 3 \\ & y_1,\ y_2 \ge 0 \end{aligned}$$

- (minus)

(C)
$$\begin{aligned} \text{maximize} \quad & 8y_1 + 10y_2 \\ \text{subject to} \quad & -2y_1 + 2y_2 \ge 5 \\ & -3y_1 + 6y_2 \ge 3 \\ & y_1,\ y_2 \ge 0 \end{aligned}$$

(D)
$$\begin{aligned} \text{maximize} \quad & 8y_1 + 10y_2 \\ \text{subject to} \quad & -2y_1 + 3y_2 \le 5 \\ & 2y_1 - 6y_2 \le 3 \\ & y_1,\ y_2 \ge 0 \end{aligned}$$

Solution

The original problem is called the *primal problem*. In formulating the dual, there is one dual variable for each primal constraint. The right-hand-side values of the primal form the optimization function coefficients for the dual, and the optimization function coefficients for the primal form the right-hand-side values for the dual. Likewise, the columns of the constraint matrix of the primal are the rows of the constraint matrix for the dual. When the primal problem is in what is called *canonical* form, the dual is easy to formulate. The canonical form is dependent on the sense of optimization (max or min). The canonical forms of the primal problem and their corresponding dual problems are given as follows. For these problems, P stands for the primal problem, D for the dual problem, and s.t. for subject to.

(P) max cx s.t. $Ax \le b$, $x \ge 0$ (D) min $b^T y$ s.t. $A^T y \ge 0$, $y \ge 0$

(P) min cx s.t. $Ax \ge b$, $x \ge 0$ (D) max $b^T y$ s.t. $A^T y \le 0$, $y \ge 0$

The problem stated is of the canonical form given by the first primal and dual problem. Therefore, the dual is given by choice (B).

The answer is B.

Problem 32

Interpret the information contained in the following decision table.

HOLE	X
TOLERANCE > 0.01	
0.01 m, TOLERANCE > 0.002	
TOLERANCE [0.002	X
drill	X
semi-finish bore	X
finish bore	X

(Note: TOLERANCE [0.002 implies that the hole can be greater than specified by at most 0.002, but not less than specification. 0.01 μ is the surface finish.)

(A) If the part has a hole and tolerance [0.002, then drill and semi-finish bore.

(B) If the part has a hole and tolerance [0.002, then drill, semi-finish bore, and finish bore.

(C) If the part has a hole and $0.002 <$ tolerance, 0.01 μ, then drill, semi-finish bore, and finish bore.

(D) If the part has a hole and tolerance > 0.01, then drill and finish bore.

Solution

A decision table summarizes different IF-THEN conditional information. The first column lists the IF conditions in the shaded top rows and the THEN consequences in the unshaded bottom rows. The columns to the right list the different production rules. The table in Prob. 32 shows one production rule. The pertinent IF-THEN statements are denoted by an X mark. The production rule states that IF there is a hole feature with a tolerance [0.002, THEN use drill, semi-finish bore, and finish bore operations.

The answer is B.

$$\frac{25\% - i}{1.44 - 1.5} = \frac{25\% - 20\%}{1.44 - 1.5278}$$

$$i = \sout{0.1966 \quad (20\%)} \quad 0.2158\ (22\%)$$

The answer is ~~B~~. C

4.

cost factor (piece)	brass-copper alloy	plastic molding
casting	(25 lbm)($3.35/lbm) = $83.75	(16 lbm)($7.40/lbm) = $118.40
machining	$6.00	0.00
weight penalty	(25 lbm − 16 lbm)($4/lbm) = $36.00	0.00
total cost	$125.75	$118.40

The plastic molding should be selected to save $\$125.75 - \$118.40 = \$7.35$ over the lifecycle of each radiator.

The answer is C.

5. Determine the cost of producing 15,000 pieces for each tool material.

$$\begin{aligned}\text{total cost} &= (\text{tool cost})(\text{no. of tools needed}) \\ &\quad + \left(\frac{\text{labor cost}}{\text{hr}}\right)(\text{hr needed})\end{aligned}$$

$$\text{tools needed} = \frac{\text{pieces required}}{\left(\frac{\text{pieces}}{\text{hr}}\right)\left(\frac{\text{tool life in hr}}{\text{tool}}\right)}$$

$$\begin{aligned}\text{hours needed} &= \text{production time} \\ &\quad + \text{tool changing time} \\ &= \frac{\text{pieces required}}{\frac{\text{pieces}}{\text{hr}}} \\ &\quad + \left(1\ \frac{\text{hr}}{\text{tool}}\right)(\text{no. of tools needed})\end{aligned}$$

For material A,

$$\text{tools needed} = \frac{15{,}000 \text{ pieces}}{\left(100\ \frac{\text{pieces}}{\text{hr}}\right)\left(50\ \frac{\text{hr}}{\text{tool}}\right)} = 3 \text{ tools}$$

$$\text{hours needed} = \frac{15{,}000 \text{ pieces}}{100\ \frac{\text{pieces}}{\text{hr}}} + \left(1\ \frac{\text{hr}}{\text{tool}}\right)(3 \text{ tools}) = 153 \text{ hr}$$

$$\begin{aligned}\text{total cost} &= \left(100\ \frac{\$}{\text{tool}}\right)(3 \text{ tools}) \\ &\quad + \left(18\ \frac{\$}{\text{hr}}\right)(153 \text{ hr}) \\ &= \$3054\end{aligned}$$

For material B,

$$\text{tools needed} = \frac{15{,}000 \text{ pieces}}{\left(75\ \frac{\text{pieces}}{\text{hr}}\right)\left(25\ \frac{\text{hr}}{\text{tool}}\right)} = 8 \text{ tools}$$

$$\text{hours needed} = \frac{15{,}000 \text{ pieces}}{75\ \frac{\text{pieces}}{\text{hr}}} + \left(1\ \frac{\text{hr}}{\text{tool}}\right)(8 \text{ tools}) = 208 \text{ hr}$$

$$\begin{aligned}\text{total cost} &= \left(30\ \frac{\$}{\text{tool}}\right)(8 \text{ tools}) \\ &\quad + \left(18\ \frac{\$}{\text{hr}}\right)(208 \text{ hr}) \\ &= \$3984\end{aligned}$$

Material A should be selected. The savings are $\$3984 - \$3054 = \$930$.

The answer is A.

6. To minimize project cost, set the first derivative of the project cost equation (with respect to project length) equal to zero and solve for the project length, T.

$$\begin{aligned}\frac{d(\text{project cost})}{dT} &= -\frac{\$4000 \text{ mo}}{T^2} + \frac{\$500T}{\text{mo}^2} = 0 \\ \$500T^3 &= \$4000 \text{ mo}^3 \\ T &= \sqrt[3]{8 \text{ mo}^3} \\ &= 2 \text{ mo}\end{aligned}$$

To find the expected project cost, substitute $T = 2$ months into the project cost equation.

$$\begin{aligned}\text{project cost} &= \$5000 + \frac{\$4000 \text{ mo}}{T} + \frac{\$250T^2}{\text{mo}^2} \\ &= \$5000 + \frac{\$4000 \text{ mo}}{2 \text{ mo}} \\ &\quad + \frac{(\$250)(2 \text{ mo})^2}{\text{mo}^2} \\ &= \$8000\end{aligned}$$

The answer is C.

7. To calculate the benefit-cost ratio for the new Colorado State Park, first classify the benefits and costs.

benefits = ($3 per person entry fee + $15 per person positive economic impact)(500,000 people per year)
= $9,000,000 per year

costs = $20,000,000 development cost at t_0 and $2,000,000 per year operating expense workstation, and the job requires only one lift per cycle. The standard time for this job is 1.6 min per unit. The maximum permissible weight limit (in pounds per force) for this lifting task according to the NIOSH formula is most nearly

(A) 18 lbf
(B) 53 lbf
(C) 78 lbf
(D) 81 lbf

48. A cart is being designed to be pushed by an operator. The cart will be used to deliver material from the warehouse to the housewares section of a large department store. It is very important that the operator be able to see over the top of the cart to avoid customers who may be shopping in the area. Assuming an average shoe height of 2 cm, the maximum height of the cart should be approximately

(A) 140 cm
(B) 151 cm
(C) 153 cm
(D) 161 cm

49. A box weighing 40 lbf rests on a table. At the beginning of the lift, the horizontal distance of the hands grasping the box from the body's center of gravity is 28 in. The height of the table is 40 in. The overcoming moment required by the body to lift the package is most nearly

(A) 95 ft-lbf
(B) 100 ft-lbf
(C) 150 ft-lbf
(D) 200 ft-lbf

50. A time study consists of four elements, with element number 2 being a machine-control element. Element 4 occurs every fifth cycle. The operator is rated at 110% for all elements that are not machine controlled. Allowances for this task are 20%, and the following table shows the average observed time for each element.

element	average observed time (min)
1	0.14
2	2.12
3	0.16
4	~~6.28~~ 5.28

What is most nearly the standard time for this task?

(A) 3.68 min
(B) 4.22 min
(C) 4.34 min
(D) 4.59 min

51. The following table summarizes the results of 200 observations to determine the delays in an operation.

~~delay~~ observed activity	no. of times observed
lack of material	25
maintenance	20
quality check	5
machine operating	150

It is desired that the error for the delay activities be no larger than ±3% with a confidence of 95%. Approximately how many total observations are required of this task?

(A) 110
(B) 390
(C) 470
(D) 850

52. A job shop has an order for 20 units of part XYZ. If the first unit will take 10 hours to produce, and it is estimated that there is a 90% learning curve for this type of work, approximately how much time should be budgeted for the completion of the entire order?

(A) 50 hr
(B) 130 hr
(C) 150 hr
(D) 200 hr

53. Which of the following are examples of typical input/output ratios used by companies to measure their performance?

(A) profit/sales, sales/employee, capacity used/max capacity, profit/total investment
(B) profit/sales, inventory/advertising cost, orders/delivery, average pay/employee
(C) material cost/sales, employees/department, profit/total investment, defects/order
(D) employees/max capacity, sales/employee, sales/fixed assets, cost/unit

54. *Process capability* is defined as the ability of the process to meet design specifications. Every process has inherent variability, which can be measured. One measure of process capability is defined as

$$C_x = \frac{\text{USL}_x - \text{LSL}_x}{6\sigma_x}$$