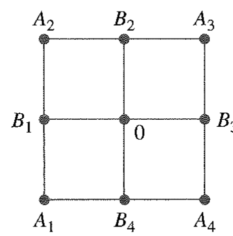
a. X = the number of unbroken eggs in a randomly chosen standard egg carton
b. Y = the number of students on a class list for a particular course who are absent on the first day of classes
c. U = the number of times a duffer has to swing at a golf ball before hitting it
d. X = the length of a randomly selected rattlesnake
e. Z = the amount of royalties earned from the sale of a first edition of 10,000 textbooks
f. Y = the pH of a randomly chosen soil sample
g. X = the tension (psi) at which a randomly selected tennis racket has been strung
h. X = the total number of coin tosses required for three individuals to obtain a match (*HHH* or *TTT*)

8. Each time a component is tested, the trial is a success (S) or failure (F). Suppose the component is tested repeatedly until a success occurs on three *consecutive* trials. Let Y denote the number of trials necessary to achieve this. List all outcomes corresponding to the five smallest possible values of Y, and state which Y value is associated with each one.

9. An individual named Claudius is located at the point 0 in the accompanying diagram.



Using an appropriate randomization device (such as a tetrahedral die, one having four sides), Claudius first moves to one of the four locations B_1, B_2, B_3, B_4. Once at one of these locations, another randomization device is used to decide whether Claudius next returns to 0 or next visits one of the other two adjacent points. This process then continues; after each move, another move to one of the (new) adjacent points is determined by tossing an appropriate die or coin.
a. Let X = the number of moves that Claudius makes before first returning to 0. What are possible values of X? Is X discrete or continuous?
b. If moves are allowed also along the diagonal paths connecting 0 to A_1, A_2, A_3, and A_4, respectively, answer the questions in part (a).

10. The number of pumps in use at both a six-pump station and a four-pump station will be determined. Give the possible values for each of the following random variables:
a. T = the total number of pumps in use
b. X = the difference between the numbers in use at stations 1 and 2
c. U = the maximum number of pumps in use at either station
d. Z = the number of stations having exactly two pumps in use

3.2 Probability Distributions for Discrete Random Variables

Probabilities assigned to various outcomes in $\mathcal{S}$ in turn determine probabilities associated with the values of any particular rv X. The *probability distribution of X* says how the total probability of 1 is distributed among (allocated to) the various possible X values. Suppose, for example, that a business has just purchased four laser printers, and let X be the number among these that require service during the warranty period. Possible X values are then 0, 1, 2, 3, and 4. The probability distribution will tell us how the probability of 1 is subdivided among these five possible values—how much probability is associated with the X value 0, how much is apportioned to the X value 1, and so on. We will use the following notation for the probabilities in the distribution:

$$p(0) = \text{the probability of the } X \text{ value } 0 = P(X = 0)$$
$$p(1) = \text{the probability of the } X \text{ value } 1 = P(X = 1)$$

and so on. In general, $p(x)$ will denote the probability assigned to the value x.

Example 3.7 The Cal Poly Department of Statistics has a lab with six computers reserved for statistics majors. Let X denote the number of these computers that are in use at a particular time of day. Suppose that the probability distribution of X is as given in the

PROPOSITION

For any two numbers a and b with $a \le b$,

$$P(a \le X \le b) = F(b) - F(a-)$$

where "$a-$" represents the largest possible X value that is strictly less than a. In particular, if the only possible values are integers and if a and b are integers, then

$$\begin{aligned} P(a \le X \le b) &= P(X = a \text{ or } a + 1 \text{ or}\ldots \text{ or } b) \\ &= F(b) - F(a - 1) \end{aligned}$$

Taking $a = b$ yields $P(X = a) = F(a) - F(a - 1)$ in this case.

The reason for subtracting $F(a-)$ rather than $F(a)$ is that we want to include $P(X = a)$; $F(b) - F(a)$ gives $P(a < X \le b)$. This proposition will be used extensively when computing binomial and Poisson probabilities in Sections 3.4 and 3.6.

Example 3.15 Let X = the number of days of sick leave taken by a randomly selected employee of a large company during a particular year. If the maximum number of allowable sick days per year is 14, possible values of X are 0, 1, . . . , 14. With $F(0) = .58$, $F(1) = .72$, $F(2) = .76$, $F(3) = .81$, $F(4) = .88$, and $F(5) = .94$,

$$P(2 \le X \le 5) = P(X = 2, 3, 4, \text{ or } 5) = F(5) - F(1) = .22$$

and

$$P(X = 3) = F(3) - F(2) = .05$$

■

EXERCISES Section 3.2 (11–28)

11. An automobile service facility specializing in engine tune-ups knows that 45% of all tune-ups are done on four-cylinder automobiles, 40% on six-cylinder automobiles, and 15% on eight-cylinder automobiles. Let X = the number of cylinders on the next car to be tuned.

a. What is the pmf of X?

b. Draw both a line graph and a probability histogram for the pmf of part (a).

c. What is the probability that the next car tuned has at least six cylinders? More than six cylinders?

12. Airlines sometimes overbook flights. Suppose that for a plane with 50 seats, 55 passengers have tickets. Define the random variable Y as the number of ticketed passengers who actually show up for the flight. The probability mass function of Y appears in the accompanying table.

y	45	46	47	48	49	50	51	52	53	54	55
$p(y)$	.05	.10	.12	.14	.25	.17	.06	.05	.03	.02	.01

a. What is the probability that the flight will accommodate all ticketed passengers who show up?

b. What is the probability that not all ticketed passengers who show up can be accommodated?

c. If you are the first person on the standby list (which means you will be the first one to get on the plane if there are any seats available after all ticketed passengers have been accommodated), what is the probability that you will be able to take the flight? What is this probability if you are the third person on the standby list?

13. A mail-order computer business has six telephone lines. Let X denote the number of lines in use at a specified time. Suppose the pmf of X is as given in the accompanying table.

x	0	1	2	3	4	5	6
$p(x)$	.10	.15	.20	.25	.20	.06	.04

Calculate the probability of each of the following events.

a. {at most three lines are in use}

b. {fewer than three lines are in use}

c. {at least three lines are in use}

d. {between two and five lines, inclusive, are in use}

e. {between two and four lines, inclusive, are not in use}

f. {at least four lines are not in use}

The absolute value is necessary because a might be negative, yet a standard deviation cannot be. Usually multiplication by a corresponds to a change in the unit of measurement (e.g., kg to lb or dollars to euros). According to the first relation in (3.14), the sd in the new unit is the original sd multiplied by the conversion factor. The second relation says that adding or subtracting a constant does not impact variability; it just rigidly shifts the distribution to the right or left.

Example 3.26 In the computer sales scenario of Example 3.23, $E(X) = 2$ and

$$E(X^2) = (0)^2(.1) + (1)^2(.2) + (2)^2(.3) + (3)^2(.4) = 5$$

so $V(X) = 5 - (2)^2 = 1$. The profit function $h(X) = 800X - 900$ then has variance $(800)^2 \cdot V(X) = (640{,}000)(1) = 640{,}000$and standard deviation 800. ■

EXERCISES Section 3.3 (29–45)

29. The pmf of the amount of memory X (GB) in a purchased flash drive was given in Example 3.13 as

x	1	2	4	8	16
$p(x)$	.05	.10	.35	.40	.10

Compute the following:

a. $E(X)$
b. $V(X)$ directly from the definition
c. The standard deviation of X
d. $V(X)$ using the shortcut formula

30. An individual who has automobile insurance from a certain company is randomly selected. Let Y be the number of moving violations for which the individual was cited during the last 3 years. The pmf of Y is

y	0	1	2	3
$p(y)$	.60	.25	.10	.05

a. Compute $E(Y)$.
b. Suppose an individual with Y violations incurs a surcharge of $\$100Y^2$. Calculate the expected amount of the surcharge.

31. Refer to Exercise 12 and calculate $V(Y)$ and σ_Y. Then determine the probability that Y is within 1 standard deviation of its mean value.

32. An appliance dealer sells three different models of upright freezers having 13.5, 15.9, and 19.1 cubic feet of storage space, respectively. Let X = the amount of storage space purchased by the next customer to buy a freezer. Suppose that X has pmf

x	13.5	15.9	19.1
$p(x)$	.2	.5	.3

a. Compute $E(X)$, $E(X^2)$, and $V(X)$.
b. If the price of a freezer having capacity X cubic feet is $25X - 8.5$, what is the expected price paid by the next customer to buy a freezer?
c. What is the variance of the price $25X - 8.5$ paid by the next customer?
d. Suppose that although the rated capacity of a freezer is X, the actual capacity is $h(X) = X - .01X^2$. What is the expected actual capacity of the freezer purchased by the next customer?

33. Let X be a Bernoulli rv with pmf as in Example 3.18.

a. Compute $E(X^2)$.
b. Show that $V(X) = p(1 - p)$.
c. Compute $E(X^{79})$.

34. Suppose that the number of plants of a particular type found in a rectangular sampling region (called a quadrat by ecologists) in a certain geographic area is an rv X with pmf

$$p(x) = \begin{cases} c/x^3 & x = 1, 2, 3, \ldots \\ 0 & \text{otherwise} \end{cases}$$

Is $E(X)$ finite? Justify your answer (this is another distribution that statisticians would call heavy-tailed).

35. A small market orders copies of a certain magazine for its magazine rack each week. Let X = demand for the magazine, with pmf

x	1	2	3	4	5	6
$p(x)$	$\frac{1}{15}$	$\frac{2}{15}$	$\frac{3}{15}$	$\frac{4}{15}$	$\frac{3}{15}$	$\frac{2}{15}$

Suppose the store owner actually pays \$2.00 for each copy of the magazine and the price to customers is \$4.00. If magazines left at the end of the week have no salvage value, is it better to order three or four copies of the magazine? [*Hint:* For both three and four copies ordered, express net revenue as a function of demand X, and then compute the expected revenue.]

PROPOSITION

If $X \sim \text{Bin}(n, p)$, then $E(X) = np$, $V(X) = np(1-p) = npq$, and $\sigma_X = \sqrt{npq}$ (where $q = 1 - p$).

Thus, calculating the mean and variance of a binomial rv does not necessitate evaluating summations. The proof of the result for $E(X)$ is sketched in Exercise 64.

Example 3.34 If 75% of all purchases at a certain store are made with a credit card and X is the number among ten randomly selected purchases made with a credit card, then $X \sim \text{Bin}(10, .75)$. Thus $E(X) = np = (10)(.75) = 7.5$, $V(X) = npq = 10(.75)(.25) = 1.875$, and $\sigma = \sqrt{1.875} = 1.37$. Again, even though X can take on only integer values, $E(X)$ need not be an integer. If we perform a large number of independent binomial experiments, each with $n = 10$ trials and $p = .75$, then the average number of S's per experiment will be close to 7.5.

The probability that X is within 1 standard deviation of its mean value is $P(7.5 - 1.37 \le X \le 7.5 + 1.37) = P(6.13 \le X \le 8.87) = P(X = 7 \text{ or } 8) = .532$. ■

EXERCISES Section 3.4 (46–67)

46. Compute the following binomial probabilities directly from the formula for $b(x; n, p)$:
a. $b(3; 8, .35)$
b. $b(5; 8, .6)$
c. $P(3 \le X \le 5)$ when $n = 7$ and $p = .6$
d. $P(1 \le X)$ when $n = 9$ and $p = .1$

47. Use Appendix Table A.1 to obtain the following probabilities:
a. $B(4; 15, .3)$
b. $b(4; 15, .3)$
c. $b(6; 15, .7)$
d. $P(2 \le X \le 4)$ when $X \sim \text{Bin}(15, .3)$
e. $P(2 \le X)$ when $X \sim \text{Bin}(15, .3)$
f. $P(X \le 1)$ when $X \sim \text{Bin}(15, .7)$
g. $P(2 < X < 6)$ when $X \sim \text{Bin}(15, .3)$

48. When circuit boards used in the manufacture of compact disc players are tested, the long-run percentage of defectives is 5%. Let X = the number of defective boards in a random sample of size $n = 25$, so $X \sim \text{Bin}(25, .05)$.
a. Determine $P(X \le 2)$.
b. Determine $P(X \ge 5)$.
c. Determine $P(1 \le X \le 4)$.
d. What is the probability that none of the 25 boards is defective?
e. Calculate the expected value and standard deviation of X.

49. A company that produces fine crystal knows from experience that 10% of its goblets have cosmetic flaws and must be classified as "seconds."
a. Among six randomly selected goblets, how likely is it that only one is a second?
b. Among six randomly selected goblets, what is the probability that at least two are seconds?
c. If goblets are examined one by one, what is the probability that at most five must be selected to find four that are not seconds?

50. A particular telephone number is used to receive both voice calls and fax messages. Suppose that 25% of the incoming calls involve fax messages, and consider a sample of 25 incoming calls. What is the probability that
a. At most 6 of the calls involve a fax message?
b. Exactly 6 of the calls involve a fax message?
c. At least 6 of the calls involve a fax message?
d. More than 6 of the calls involve a fax message?

51. Refer to the previous exercise.
a. What is the expected number of calls among the 25 that involve a fax message?
b. What is the standard deviation of the number among the 25 calls that involve a fax message?
c. What is the probability that the number of calls among the 25 that involve a fax transmission exceeds the expected number by more than 2 standard deviations?

52. Suppose that 30% of all students who have to buy a text for a particular course want a new copy (the successes!), whereas the other 70% want a used copy. Consider randomly selecting 25 purchasers.
a. What are the mean value and standard deviation of the number who want a new copy of the book?
b. What is the probability that the number who want new copies is more than two standard deviations away from the mean value?

c. The bookstore has 15 new copies and 15 used copies in stock. If 25 people come in one by one to purchase this text, what is the probability that all 25 will get the type of book they want from current stock? [*Hint:* Let X = the number who want a new copy. For what values of X will all 25 get what they want?]

d. Suppose that new copies cost \$100 and used copies cost \$70. Assume the bookstore currently has 50 new copies and 50 used copies. What is the expected value of total revenue from the sale of the next 25 copies purchased? Be sure to indicate what rule of expected value you are using. [*Hint:* Let $h(X)$ = the revenue when X of the 25 purchasers want new copies. Express this as a linear function.]

53. Exercise 30 (Section 3.3) gave the pmf of Y, the number of traffic citations for a randomly selected individual insured by a particular company. What is the probability that among 15 randomly chosen such individuals

a. At least 10 have no citations?

b. Fewer than half have at least one citation?

c. The number that have at least one citation is between 5 and 10, inclusive?*

54. A particular type of tennis racket comes in a midsize version and an oversize version. Sixty percent of all customers at a certain store want the oversize version.

a. Among ten randomly selected customers who want this type of racket, what is the probability that at least six want the oversize version?

b. Among ten randomly selected customers, what is the probability that the number who want the oversize version is within 1 standard deviation of the mean value?

c. The store currently has seven rackets of each version. What is the probability that all of the next ten customers who want this racket can get the version they want from current stock?

55. Twenty percent of all telephones of a certain type are submitted for service while under warranty. Of these, 60% can be repaired, whereas the other 40% must be replaced with new units. If a company purchases ten of these telephones, what is the probability that exactly two will end up being replaced under warranty?

56. The College Board reports that 2% of the 2 million high school students who take the SAT each year receive special accommodations because of documented disabilities (*Los Angeles Times,* July 16, 2002). Consider a random sample of 25 students who have recently taken the test.

a. What is the probability that exactly 1 received a special accommodation?

b. What is the probability that at least 1 received a special accommodation?

c. What is the probability that at least 2 received a special accommodation?

d. What is the probability that the number among the 25 who received a special accommodation is within 2 standard deviations of the number you would expect to be accommodated?

e. Suppose that a student who does not receive a special accommodation is allowed 3 hours for the exam, whereas an accommodated student is allowed 4.5 hours. What would you expect the average time allowed the 25 selected students to be?

57. Suppose that 90% of all batteries from a certain supplier have acceptable voltages. A certain type of flashlight requires two type-D batteries, and the flashlight will work only if both its batteries have acceptable voltages. Among ten randomly selected flashlights, what is the probability that at least nine will work? What assumptions did you make in the course of answering the question posed?

58. A very large batch of components has arrived at a distributor. The batch can be characterized as acceptable only if the proportion of defective components is at most .10. The distributor decides to randomly select 10 components and to accept the batch only if the number of defective components in the sample is at most 2.

a. What is the probability that the batch will be accepted when the actual proportion of defectives is .01? .05? .10? .20? .25?

b. Let p denote the actual proportion of defectives in the batch. A graph of P(batch is accepted) as a function of p, with p on the horizontal axis and P(batch is accepted) on the vertical axis, is called the *operating characteristic curve* for the acceptance sampling plan. Use the results of part (a) to sketch this curve for $0 \le p \le 1$.

c. Repeat parts (a) and (b) with "1" replacing "2" in the acceptance sampling plan.

d. Repeat parts (a) and (b) with "15" replacing "10" in the acceptance sampling plan.

e. Which of the three sampling plans, that of part (a), (c), or (d), appears most satisfactory, and why?

59. An ordinance requiring that a smoke detector be installed in all previously constructed houses has been in effect in a particular city for 1 year. The fire department is concerned that many houses remain without detectors. Let p = the true proportion of such houses having detectors, and suppose that a random sample of 25 homes is inspected. If the sample strongly indicates that fewer than 80% of all houses have a detector, the fire department will campaign for a mandatory inspection program. Because of the costliness of the program, the department prefers not to call for such inspections unless sample evidence strongly argues for their necessity. Let X denote the number of homes with detectors among the 25 sampled. Consider rejecting the claim that $p \ge .8$ if $x \le 15$.

a. What is the probability that the claim is rejected when the actual value of p is .8?

b. What is the probability of not rejecting the claim when $p = .7$? When $p = .6$?

c. How do the "error probabilities" of parts (a) and (b) change if the value 15 in the decision rule is replaced by 14?

* "Between a and b, inclusive" is equivalent to $(a \le X \le b)$.

EXERCISES Section 3.5 (68–78)

68. An electronics store has received a shipment of 20 table radios that have connections for an iPod or iPhone. Twelve of these have two slots (so they can accommodate both devices), and the other eight have a single slot. Suppose that six of the 20 radios are randomly selected to be stored under a shelf where the radios are displayed, and the remaining ones are placed in a storeroom. Let $X =$ the number among the radios stored under the display shelf that have two slots.

a. What kind of a distribution does X have (name and values of all parameters)?

b. Compute $P(X = 2)$, $P(X \leq 2)$, and $P(X \geq 2)$.

c. Calculate the mean value and standard deviation of X.

69. Each of 12 refrigerators of a certain type has been returned to a distributor because of an audible, high-pitched, oscillating noise when the refrigerators are running. Suppose that 7 of these refrigerators have a defective compressor and the other 5 have less serious problems. If the refrigerators are examined in random order, let X be the number among the first 6 examined that have a defective compressor. Compute the following:

a. $P(X = 5)$

b. $P(X \leq 4)$

c. The probability that X exceeds its mean value by more than 1 standard deviation.

d. Consider a large shipment of 400 refrigerators, of which 40 have defective compressors. If X is the number among 15 randomly selected refrigerators that have defective compressors, describe a less tedious way to calculate (at least approximately) $P(X \leq 5)$ than to use the hypergeometric pmf.

70. An instructor who taught two sections of engineering statistics last term, the first with 20 students and the second with 30, decided to assign a term project. After all projects had been turned in, the instructor randomly ordered them before grading. Consider the first 15 graded projects.

a. What is the probability that exactly 10 of these are from the second section?

b. What is the probability that at least 10 of these are from the second section?

c. What is the probability that at least 10 of these are from the same section?

d. What are the mean value and standard deviation of the number among these 15 that are from the second section?

e. What are the mean value and standard deviation of the number of projects not among these first 15 that are from the second section?

71. A geologist has collected 10 specimens of basaltic rock and 10 specimens of granite. The geologist instructs a laboratory assistant to randomly select 15 of the specimens for analysis.

a. What is the pmf of the number of granite specimens selected for analysis?

b. What is the probability that all specimens of one of the two types of rock are selected for analysis?

c. What is the probability that the number of granite specimens selected for analysis is within 1 standard deviation of its mean value?

72. A personnel director interviewing 11 senior engineers for four job openings has scheduled six interviews for the first day and five for the second day of interviewing. Assume that the candidates are interviewed in random order.

a. What is the probability that x of the top four candidates are interviewed on the first day?

b. How many of the top four candidates can be expected to be interviewed on the first day?

73. Twenty pairs of individuals playing in a bridge tournament have been seeded 1, . . . , 20. In the first part of the tournament, the 20 are randomly divided into 10 east–west pairs and 10 north–south pairs.

a. What is the probability that x of the top 10 pairs end up playing east–west?

b. What is the probability that all of the top five pairs end up playing the same direction?

c. If there are $2n$ pairs, what is the pmf of $X =$ the number among the top n pairs who end up playing east–west? What are $E(X)$ and $V(X)$?

74. A second-stage smog alert has been called in a certain area of Los Angeles County in which there are 50 industrial firms. An inspector will visit 10 randomly selected firms to check for violations of regulations.

a. If 15 of the firms are actually violating at least one regulation, what is the pmf of the number of firms visited by the inspector that are in violation of at least one regulation?

b. If there are 500 firms in the area, of which 150 are in violation, approximate the pmf of part (a) by a simpler pmf.

c. For $X =$ the number among the 10 visited that are in violation, compute $E(X)$ and $V(X)$ both for the exact pmf and the approximating pmf in part (b).

75. Suppose that $p = P(\text{male birth}) = .5$. A couple wishes to have exactly two female children in their family. They will have children until this condition is fulfilled.

a. What is the probability that the family has x male children?

b. What is the probability that the family has four children?

c. What is the probability that the family has at most four children?

d. How many male children would you expect this family to have? How many children would you expect this family to have?

EXERCISES Section 3.6 (79–93)

79. Let X, the number of flaws on the surface of a randomly selected boiler of a certain type, have a Poisson distribution with parameter $\mu = 5$. Use Appendix Table A.2 to compute the following probabilities:
a. $P(X \leq 8)$ **b.** $P(X = 8)$ **c.** $P(9 \leq X)$
d. $P(5 \leq X \leq 8)$ **e.** $P(5 < X < 8)$

80. Let X be the number of material anomalies occurring in a particular region of an aircraft gas-turbine disk. The article "Methodology for Probabilistic Life Prediction of Multiple-Anomaly Materials" (*Amer. Inst. of Aeronautics and Astronautics J.*, 2006: 787–793) proposes a Poisson distribution for X. Suppose that $\mu = 4$.
a. Compute both $P(X \leq 4)$ and $P(X < 4)$.
b. Compute $P(4 \leq X \leq 8)$.
c. Compute $P(8 \leq X)$.
d. What is the probability that the number of anomalies exceeds its mean value by no more than one standard deviation?

81. Suppose that the number of drivers who travel between a particular origin and destination during a designated time period has a Poisson distribution with parameter $\mu = 20$ (suggested in the article "Dynamic Ride Sharing: Theory and Practice," *J. of Transp. Engr.*, 1997: 308–312). What is the probability that the number of drivers will
a. Be at most 10?
b. Exceed 20?
c. Be between 10 and 20, inclusive? Be strictly between 10 and 20?
d. Be within 2 standard deviations of the mean value?

82. Consider writing onto a computer disk and then sending it through a certifier that counts the number of missing pulses. Suppose this number X has a Poisson distribution with parameter $\mu = .2$. (Suggested in "Average Sample Number for Semi-Curtailed Sampling Using the Poisson Distribution," *J. Quality Technology*, 1983: 126–129.)
a. What is the probability that a disk has exactly one missing pulse?
b. What is the probability that a disk has at least two missing pulses?
c. If two disks are independently selected, what is the probability that neither contains a missing pulse?

83. An article in the *Los Angeles Times* (Dec. 3, 1993) reports that 1 in 200 people carry the defective gene that causes inherited colon cancer. In a sample of 1000 individuals, what is the approximate distribution of the number who carry this gene? Use this distribution to calculate the approximate probability that
a. Between 5 and 8 (inclusive) carry the gene.
b. At least 8 carry the gene.

84. Suppose that only .10% of all computers of a certain type experience CPU failure during the warranty period. Consider a sample of 10,000 computers.
a. What are the expected value and standard deviation of the number of computers in the sample that have the defect?
b. What is the (approximate) probability that more than 10 sampled computers have the defect?
c. What is the (approximate) probability that no sampled computers have the defect?

85. Suppose small aircraft arrive at a certain airport according to a Poisson process with rate $\alpha = 8$ per hour, so that the number of arrivals during a time period of t hours is a Poisson rv with parameter $\mu = 8t$.
a. What is the probability that exactly 6 small aircraft arrive during a 1-hour period? At least 6? At least 10?
b. What are the expected value and standard deviation of the number of small aircraft that arrive during a 90-min period?
c. What is the probability that at least 20 small aircraft arrive during a 2.5-hour period? That at most 10 arrive during this period?

86. The number of people arriving for treatment at an emergency room can be modeled by a Poisson process with a rate parameter of five per hour.
a. What is the probability that exactly four arrivals occur during a particular hour?
b. What is the probability that at least four people arrive during a particular hour?
c. How many people do you expect to arrive during a 45-min period?

87. The number of requests for assistance received by a towing service is a Poisson process with rate $\alpha = 4$ per hour.
a. Compute the probability that exactly ten requests are received during a particular 2-hour period.
b. If the operators of the towing service take a 30-min break for lunch, what is the probability that they do not miss any calls for assistance?
c. How many calls would you expect during their break?

88. In proof testing of circuit boards, the probability that any particular diode will fail is .01. Suppose a circuit board contains 200 diodes.
a. How many diodes would you expect to fail, and what is the standard deviation of the number that are expected to fail?
b. What is the (approximate) probability that at least four diodes will fail on a randomly selected board?
c. If five boards are shipped to a particular customer, how likely is it that at least four of them will work properly? (A board works properly only if all its diodes work.)

89. The article "Reliability-Based Service-Life Assessment of Aging Concrete Structures" (*J. Structural Engr.*, 1993: 1600–1621) suggests that a Poisson process can be used to represent the occurrence of structural loads over time. Suppose the mean time between occurrences of loads is .5 year.