b. Repair calls are handled by one repairman at a photocopy shop. Repair time, including travel time, is exponentially distributed, with a mean of two hours per call. Requests for copier repairs come in at a mean rate of three per eight-hour day (assume Poisson). Determine the following:
   (1) The average number of customers awaiting repairs
   (2) System utilization
   (3) The amount of time during an eight-hour day that the repairman is not out on a call
   (4) The probability of two or more customers in the system

c. An average of 18 customers arrive at a service center each hour. There are two servers on duty, and each server can process 12 customers per hour.
   (1) What is the system utilization?
   (2) What is the average number of customers in the system (waiting plus being served)?
   (3) What is the average time customers wait in line for service?
   (4) What is the average waiting time for customers who actually have to wait?

2. A vending machine dispenses hot chocolate or coffee. Service time is 30 seconds per cup and is constant. Customers arrive at a mean rate of 80 per hour, and this rate is Poisson-distributed. Determine the following:
   a. The average number of customers waiting in line
   b. The average time customers spend in the system
   c. The average number in the system

3. Many of a bank's customers use its automatic teller machine to transact business after normal banking hours. During the early evening hours in the summer months, customers arrive at a certain location at the rate of one every other minute. This can be modeled using a Poisson distribution. Each customer spends an average of 90 seconds completing his or her transactions. Transaction time is exponentially distributed. Determine the following:
   a. The average time customers spend at the machine, including waiting in line and completing transactions
   b. The probability that a customer will not have to wait upon arriving at the automatic teller machine
   c. The average number waiting to use the machine

4. The following information pertains to telephone calls to a motel on a typical Tuesday.

Period	Incoming Rate (calls per minute)	Service Rate (calls per minute per operator)	Number of Operators
Morning	1.8	1.5	2
Afternoon	2.2	1.0	3
Evening	1.4	0.7	3

   a. Determine the average time callers wait to have their calls answered for each period and the probability that a caller will have to wait for each period.
   b. For each case in the previous problem, determine the maximum line length for a probability of 96 percent.

5. A small town with one hospital has two ambulances to supply ambulance service. Requests for ambulances during non-holiday weekends average .45 per hour and tend to be Poisson-distributed. Travel and assistance time averages two hours per call and follows an exponential distribution. Find:
   a. System utilization
   b. The average number of customers waiting
   c. The average time customers wait for an ambulance
   d. The probability that *both* ambulances will be busy when a call comes in

6. Trucks are required to pass through a weighing station so they can be checked for weight violations. Trucks arrive at the station at the rate of 40 an hour between 7:00 p.m. and 9:00 p.m. Currently two inspectors are on duty during those hours, each of whom can inspect 25 trucks an hour.
   a. How many trucks would you expect to see at the weighing station, including those being inspected?

b. If a truck was just arriving at the station, about how many minutes could the driver expect to be at the station?

c. What is the probability that both inspectors would be busy at the same time?

d. How many minutes, on average, would a truck that is not immediately inspected have to wait?

e. What condition would exist if there was only one inspector?

f. What is the maximum line length for a probability of .97?

7. The manager of a regional warehouse must decide on the number of loading docks to request for a new facility in order to minimize the sum of dock costs and driver–truck costs. The manager has learned that each driver–truck combination represents a cost of $300 per day and that each dock plus loading crew represents a cost of $1,100 per day.

   a. How many docks should be requested if trucks arrive at the rate of three per day, each dock can handle five trucks per day, and both rates are Poisson?

   b. An employee has proposed adding new equipment that would speed up the loading rate to 6 trucks per day. The equipment would cost $100 per day for each dock. Should the manager invest in the new equipment?

8. The parts department of a large automobile dealership has a counter used exclusively for mechanics' requests for parts. The time between requests can be modeled by a negative exponential distribution that has a mean of five minutes. A clerk can handle requests at a rate of 15 per hour, and this can be modeled by a Poisson distribution that has a mean of 15. Suppose there are two clerks at the counter.

   a. On average, how many mechanics would be at the counter, including those being served?

   b. What is the probability that a mechanic would have to wait for service?

   c. If a mechanic has to wait, how long would the average wait be?

   d. What percentage of time are the clerks idle?

   e. If clerks represent a cost of $20 per hour and mechanics a cost of $30 per hour, what number of clerks would be optimal in terms of minimizing total cost?

9. One field representative services five customers for a computer manufacturer. Customers request assistance at an average (Poisson-distributed) rate of once every four working days. The field representative can handle an average (Poisson-distributed) of one call per day. Determine the following:

   a. The expected number of customers waiting

   b. The average length of time customers must wait from the initial request for service until the service has been completed

   c. The percentage of time the service rep will be idle

   d. How much your answer to part *a* would be reduced if a second field rep were added

10. Two operators handle adjustments for a group of 10 machines. Adjustment time is exponentially distributed and has a mean of 14 minutes per machine. The machines operate for an average of 86 minutes between adjustments. While running, each machine can turn out 50 pieces per hour. Find the following:

    a. The probability that a machine will have to wait for an adjustment

    b. The average number of machines waiting for adjustment

    c. The average number of machines being serviced

    d. The expected hourly output of each machine, taking adjustments into account

    e. Machine downtime represents a cost of $70 per hour; operator cost (including salary and fringe benefits) is $15 per hour. What is the optimum number of operators?

11. One operator services a bank of five machines. Machine running time and service time are both exponential. Machines run for an average of 90 minutes between service requirements, and service time averages 35 minutes. The operator receives $20 per hour in salary and fringe benefits, and machine downtime costs $70 per hour per machine.

    a. If each machine produces 60 pieces per hour while running, find the average hourly output of each machine, when waiting and service times are taken into account.

    b. Determine the optimum number of operators.