HW Queue 3 (Waiting Line) Model and Applications Name: _____
Problems 18, 19 and 20 on pages 668 and 669 of your text. Answers are given on BB. You do not need to hand them in.

(The HWQueue 3 is a continuation of HW Queues 1 and 2 Reference of related lecture items is given for your convenience, i.e., 1.e. refers to Queuing Lecture Problem 1, question e.)

Bank of America (BoA) in Harrisonburg in Harrisonburg has a single drive-in teller window. Customers arrive at the window about every 10 minutes on average according to a Poisson process or the hourly arrival rate is $\lambda = 6$. It take an average of five minutes (exponentially distributed) to complete each customer order or the hourly service rate is $\mu = 12$.

1. (1.e) What is the probability of more than 3 customers arriving to the window in a 30-minute period?
   a. What is the equation with the notation and the answer for the problem?

   b. What is the Excel@ formula to be used to get the same solution? (Please test it out first)

2. (1.j) What is the chance it will take more than 3 minutes to serve a customer at the window?
   a. What is the equation with the notation and the answer for the problem?

   b. What is the Excel@ formula to be used to get the same solution? (Please test it out first)

3. (2.) Assume BoA pays $25 per hour for each server, and the cost of customers' waiting to be served is $0.30 per minute. What is the hourly average cost for BoA to operate M/M/1 window as given above?

4. (1.t) Suppose that the business at BoA increases by 60% in Friday afternoon, (You should use Q.xls and be sure to provide adequate explanations)
   a. Can one window handle the increased volume? Support your answer.

   b. How are customers' average waiting times affected?

   c. (1.s and 2) What is the total hourly operating cost for BoA if one window is open?

   d. What is the total hourly operating cost for BoA if two windows are open?

   e. (4.) Would you recommend BoA to open three windows for the situation? Why and Why not?

   f. What is the P_0 for BoA with three windows open for services?

5. (2.) Suppose that BoA opens a second (identical) window, with average service rate $\mu = 12$ per hour per server and average arrival rate of $\lambda = 9.6$ per hour.
   a. On average, what percentage of the time are the employees busy at each window?

   b. What is the value of P_0 for this queuing system (s=2)?

   c. What is the chance that there is at least one customer in the system?

   d. What is the average number of customers waiting to be served?

   e. What is the average number of customers in BoA?

   f. What is the average amount of time spent in line by customers at BoA?

   g. What is the probability that a customer will have to wait in line to be served at BoA?

   h. Once the service is started, how long on the average it takes for a customer to get served?

i. How long, on average, does it take a customer to be served at BoA?

j. What is the probability there are two customers at BoA?

k. What is the probability there are more than two customers waiting to be served?

6. (5.) Suppose that on a particular Friday at BoA, businesses at BoA actually increases so that customers are arriving about every 3 minutes, on average. There are two windows open for service, and it still takes an average of 5 minutes (exponential distributed) to serve each customer.
   a. What is a customer's average waiting time if there is one line and customers go to the first open window?

   b. What is the total cost per hour if there is one line and customers go to the first open window?

   c. What is a customer's average waiting time if there is a separate line for each window and we assume that approximately half of the customers join each line?

   d. What is the total cost per hour if there is a separate line for each window and we assume that approximately half of the customers join each line?