Q3.3 **(Cranberries)** International Cranberry Uncooperative (ICU) is a competitor to the National Cranberry Cooperative (NCC). At ICU, barrels of cranberries arrive on trucks at a rate of 150 barrels per hour and are processed continuously at a rate of 100 barrels per hour. Trucks arrive at a uniform rate over eight hours, from 6:00 a.m. until 2:00 p.m. Assume the trucks are sufficiently small so that the delivery of cranberries can be treated as a continuous inflow. The first truck arrives at 6:00 a.m. and unloads immediately, so processing begins at 6:00 a.m. The bins at ICU can hold up to 200 barrels of cranberries before overflowing. If a truck arrives and the bins are full, the truck must wait until there is room in the bins.

a. What is the maximum number of barrels of cranberries that are waiting on the trucks at any given time?

b. At what time do the trucks stop waiting?

c. At what time do the bins become empty?

d. ICU is considering using seasonal workers in addition to their regular workforce to help with the processing of cranberries. When the seasonal workers are working, the processing rate increases to 125 barrels per hour. The seasonal workers would start working at 10:00 a.m. and finish working when the trucks stop waiting. At what time would ICU finish processing the cranberries using these seasonal workers?

Q3.4 **(Western Pennsylvania Milk Company)** The Western Pennsylvania Milk Company is producing milk at a fixed rate of 5,000 gallons/hour. The company's clients request 100,000 gallons of milk over the course of one day. This demand is spread out uniformly from 8 a.m. to 6 p.m. If there is no milk available, clients will wait until enough is produced to satisfy their requests.

The company starts producing at 8 a.m. with 25,000 gallons in finished goods inventory. At the end of the day, after all demand has been fulfilled, the plant keeps on producing until the finished goods inventory has been restored to 25,000 gallons.

When answering the following questions, treat trucks/milk as a continuous flow process. Begin by drawing a graph indicating how much milk is in inventory and how much milk is "back-ordered" over the course of the day.

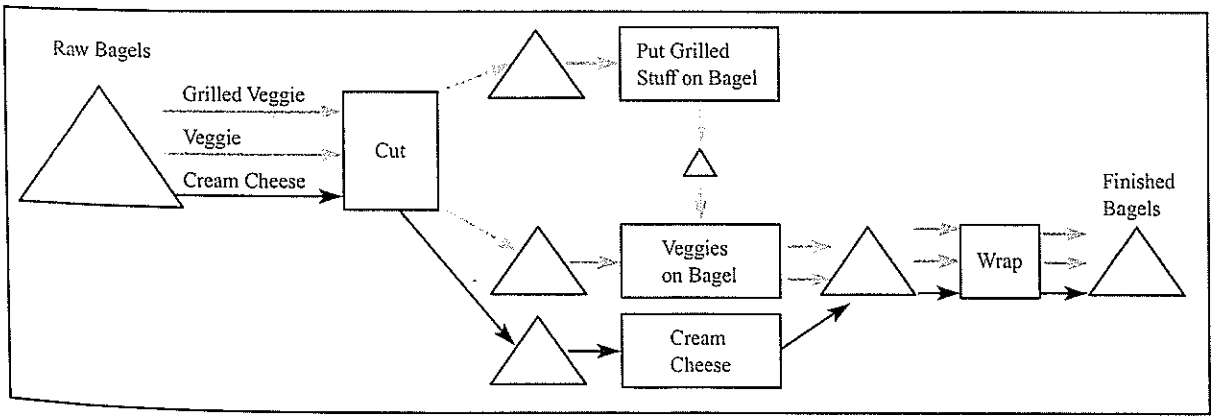
a. At what time during the day will the clients have to start waiting for their requests to be filled?

b. At what time will clients stop waiting?

c. Assume that the milk is picked up in trucks that hold 1,250 gallons each. What is the maximum number of trucks that are waiting?

d. Assume the plant is charged $50 per hour per waiting truck. What are the total waiting time charges on a day?

Q3.5** **(Bagel Store)** Consider a bagel store selling three types of bagels that are produced according to the process flow diagram outlined below. We assume the demand is 180 bagels a day, of which there are 30 grilled veggie, 110 veggie only, and 40 cream cheese. Assume that the workday is 10 hours long and each resource is staffed with one worker.



Moreover, we assume the following Processing times:

	Cut	Grilled Stuff	Veggies	Cream Cheese	Wrap
Processing time	3 [min./bagel]	10 [min./bagel]	5 [min./bagel]	4 [min./bagel]	2 [min./bagel]

Processing times are independent of which bagel type is processed at a resource (for example, cutting a bagel takes the same time for a cream cheese bagel as for a veggie bagel).

a. Where in the process is the bottleneck?

b. How many units can the process produce within one hour, assuming the product mix has to remain constant?

Q3.6 **(Valley Forge Income Tax Advice)** VF is a small accounting firm supporting wealthy individuals in their preparation of annual income tax statements. Every December, VF sends out a short survey to their customers, asking for the information required for preparing the tax statements. Based on 24 years of experience, VF categorizes their cases into the following groups:

- Group 1 (new customers, easy): 15 percent of cases
- Group 2 (new customers, complex): 5 percent of cases
- Group 3 (repeat customers, easy): 50 percent of cases
- Group 4 (repeat customers, complex): 30 percent of cases

Here, "easy" versus "complex" refers to the complexity of the customer's earning situation.

In order to prepare the income tax statement, VF needs to complete the following set of activities. Processing times (and even which activities need to be carried out) depend on which group a tax statement falls into. All of the following processing times are expressed in minutes per income tax statement.

Group	Filing	Initial Meeting	Preparation	Review by Senior Accountant	Writing
1	20	30	120	20	50
2	40	90	300	60	80
3	20	No meeting	80	5	30
4	40	No meeting	200	30	60

The activities are carried out by the following three persons:

- Administrative support person: filing and writing.
- Senior accountant (who is also the owner): initial meeting, review by senior accountant.
- Junior accountant: preparation.

Assume that all three persons work eight hours per day and 20 days a month. For the following questions, assume the product mix as described above. Assume that there are 50 income tax statements arriving each month.

a. Which of the three persons is the bottleneck?

b. What is the (implied) utilization of the senior accountant? The junior accountant? The administrative support person?

c. You have been asked to analyze which of the four product groups is the most profitable. Which factors would influence the answer to this?

d. How would the process capacity of VF change if a new word processing system would reduce the time to write the income tax statements by 50 percent?

Q3.7 **(Car Wash Supply Process)** CC Car Wash specializes in car cleaning services. The services offered by the company, the exact service time, and the resources needed for each of them are described in the table following:

Service	Description	Processing Time	Resource Used
A. Wash	Exterior car washing and drying	10 min.	1 automated washing machine
B. Wax	Exterior car waxing	10 min.	1 automated waxing machine
C. Wheel cleaning	Detailed cleaning of all wheels	7 min.	1 employee
D. Interior cleaning	Detailed cleaning inside the car	20 min.	1 employee

The company offers the following packages to their customers:

- Package 1: Includes only car wash (service A).
- Package 2: Includes car wash and waxing (services A and B).
- Package 3: Car wash, waxing, and wheel cleaning (services A, B, and C).
- Package 4: All four services (A, B, C, and D).

Customers of CC Car Wash visit the station at a constant rate (you can ignore any effects of variability) of 40 customers per day. Of these customers, 40 percent buy Package 1, 15 percent buy Package 2, 15 percent buy Package 3, and 30 percent buy Package 4. The mix does not change over the course of the day. The store operates 12 hours a day.

a. What is the implied utilization of the employee doing the wheel cleaning service?

b. Which resource has the highest implied utilization?

For the next summer, CC Car Wash anticipates an increase in the demand to 80 customers per day. Together with this demand increase, there is expected to be a change in the mix of packages demanded: 30 percent of the customers ask for Package 1, 10 percent for Package 2, 10 percent for Package 3, and 50 percent for Package 4. The company will install an additional washing machine to do service A.

c. What will be the new bottleneck in the process?

d. How many customers a day will not be served? Which customers are going to wait? Explain your reasoning!

Q3.8 **(Starbucks)** After an "all night" study session the day before their last final exam, four students decide to stop for some much-needed coffee at the campus Starbucks. They arrive at 8:30 a.m. and are dismayed to find a rather long line.

Fortunately for the students, a Starbucks executive happens to be in line directly in front of them. From her, they learn the following facts about this Starbucks location:

I. There are three employee types:
   - There is a single cashier who takes all orders, prepares nonbeverage food items, grinds coffee, and pours drip coffee.
   - There is a single frozen drink maker who prepares blended and iced drinks.
   - There is a single espresso drink maker who prepares espressos, lattes, and steamed drinks.

II. There are typically four types of customers:
   - Drip coffee customers order only drip coffee. This requires 20 seconds of the cashier's time to pour the coffee.
   - Blended and iced drink customers order a drink that requires the use of the blender. These drinks take on average 2 minutes of work of the frozen drink maker.
   - Espresso drink customers order a beverage that uses espresso and/or steamed milk. On average, these drinks require 1 minute of work of the espresso drink maker.
   - Ground coffee customers buy one of Starbucks' many varieties of whole bean coffee and have it ground to their specification at the store. This requires a total of 1 minute of the cashier's time (20 seconds to pour the coffee and 40 seconds to grind the whole bean coffee).