SIE 431/531 Simulation Modeling and Analysis （Spring 2023）
Take home exam (due on 3/21 at noon, 12pm)
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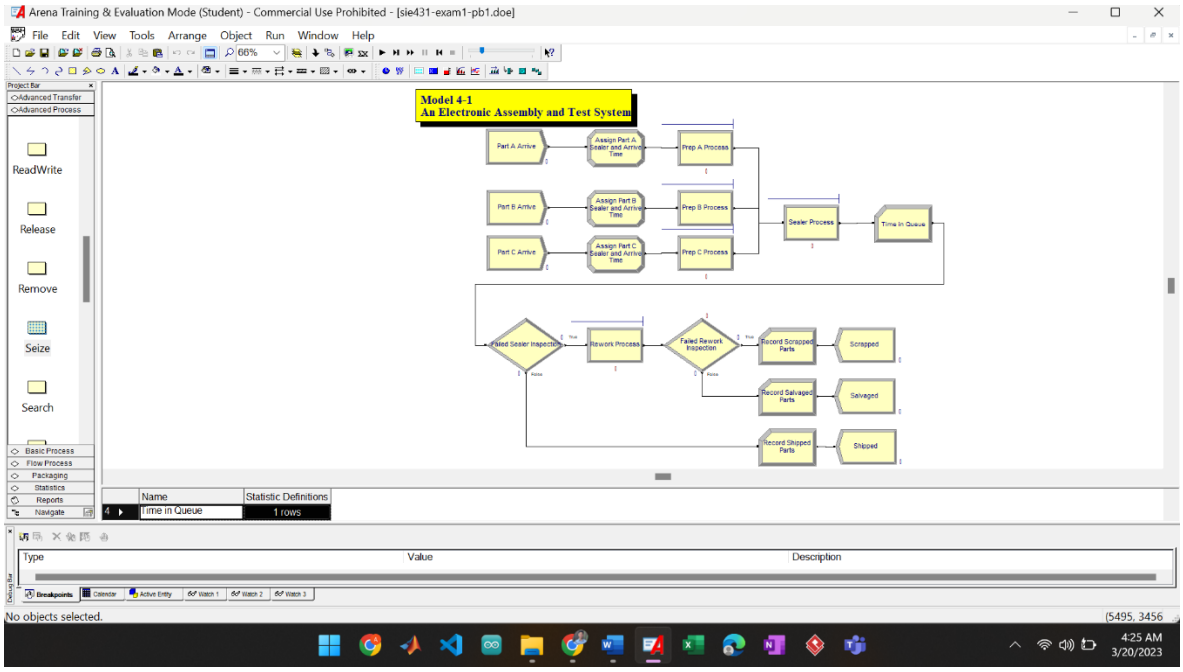
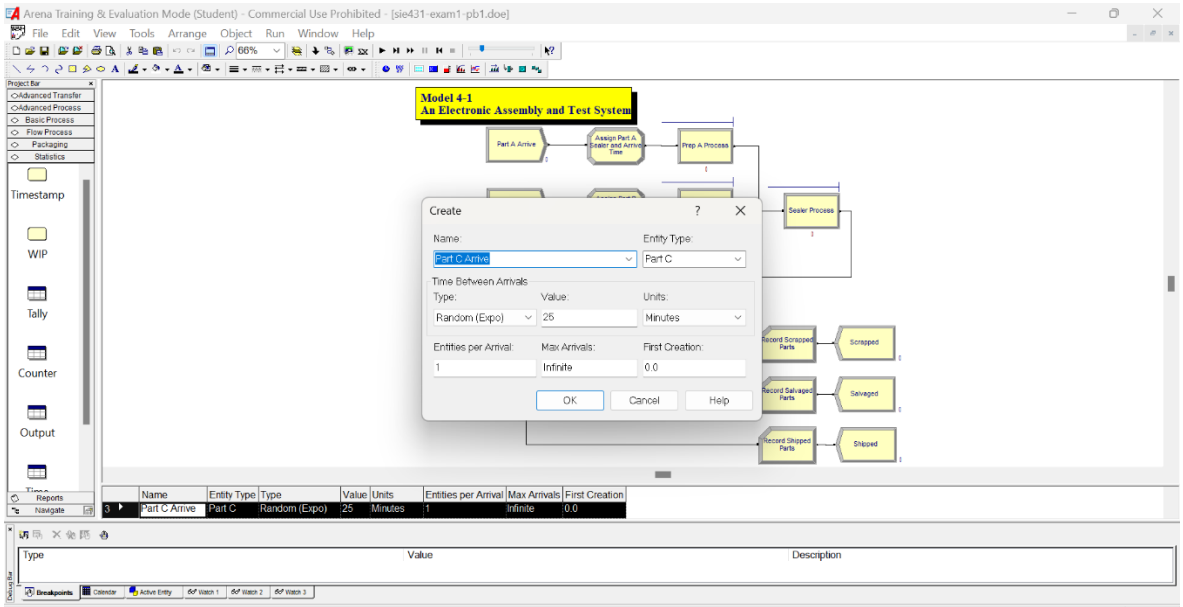
By signing here, Agustin Espinoza, I signify that I have completed the problems below independently and I have not shared my solutions with others.

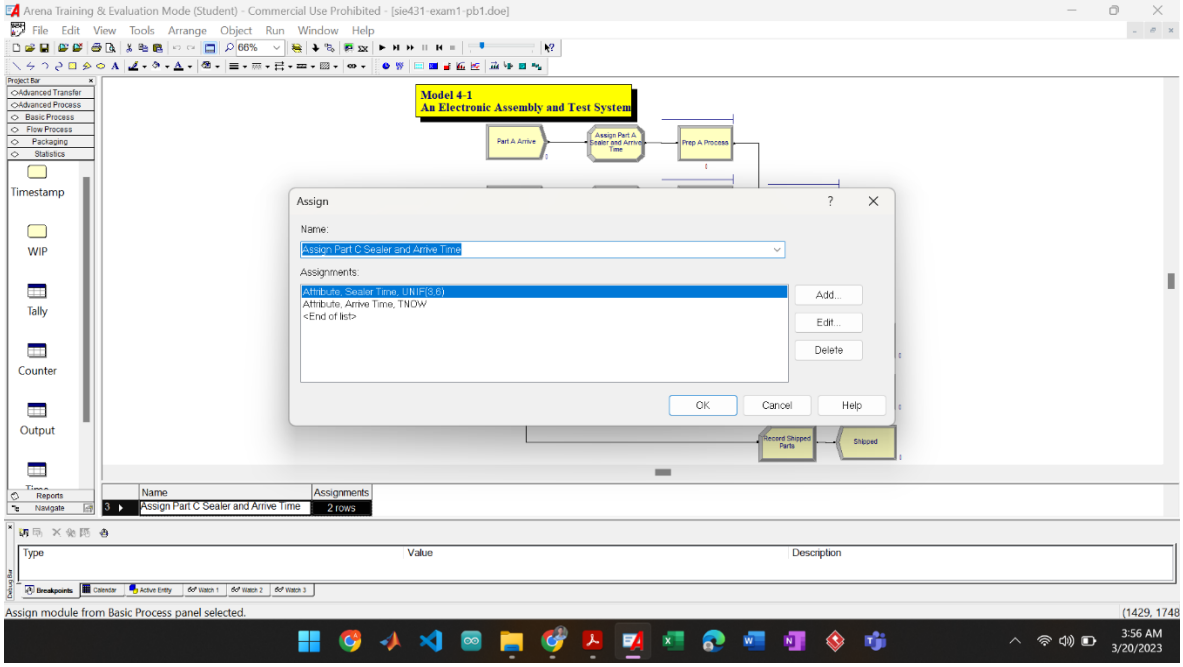
Problem 1 (20 pts)

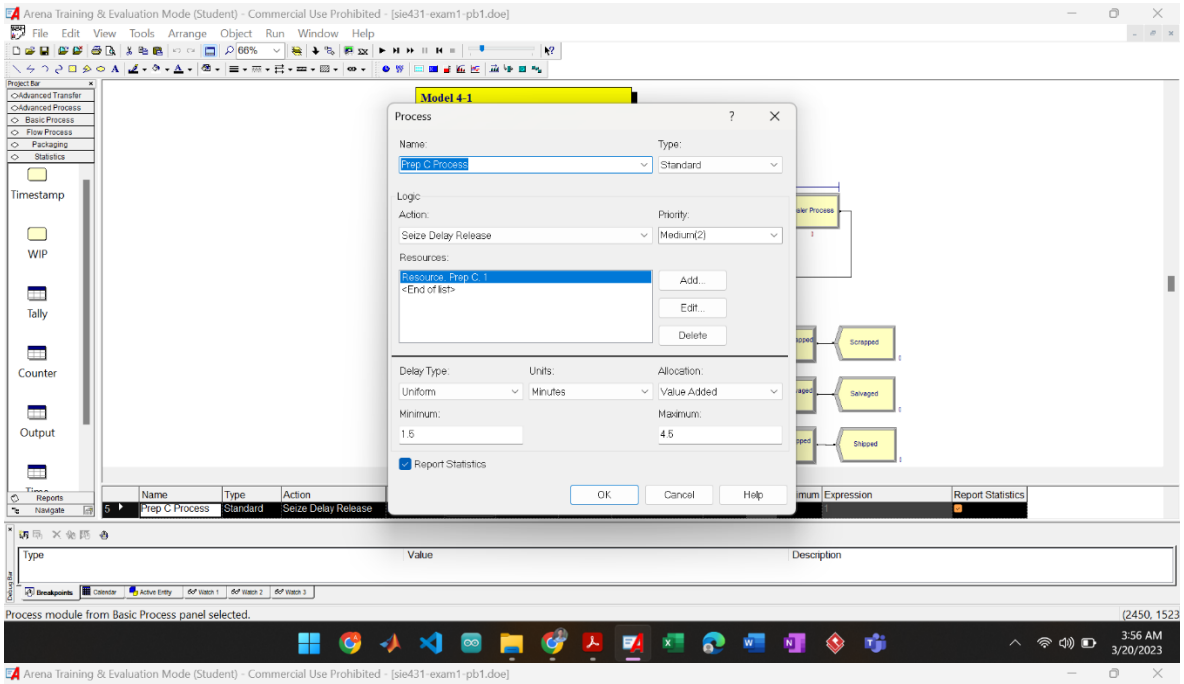
Book example 4-1 describes a sealed electronic assembly and test system in which two parts, Part A and Part B, are processed. Suppose the system is now used to process an additional part, Part C. The time between the arrivals of Part C is exponentially distributed with a mean of 25 minutes. Upon arrival, they are transferred to the Part C Prep area and then move to the Sealer Operation which is shared by Parts A and B. The Part C prep time follows a UNIF(1.5, 4.5) distribution (in minutes). The sealer time for Part C is also uniformly distributed between 3 and 6 minutes. Modify Model 4-1 to include Part C in the system and change the number of servers in the Rework station from one to two. Show the following result:

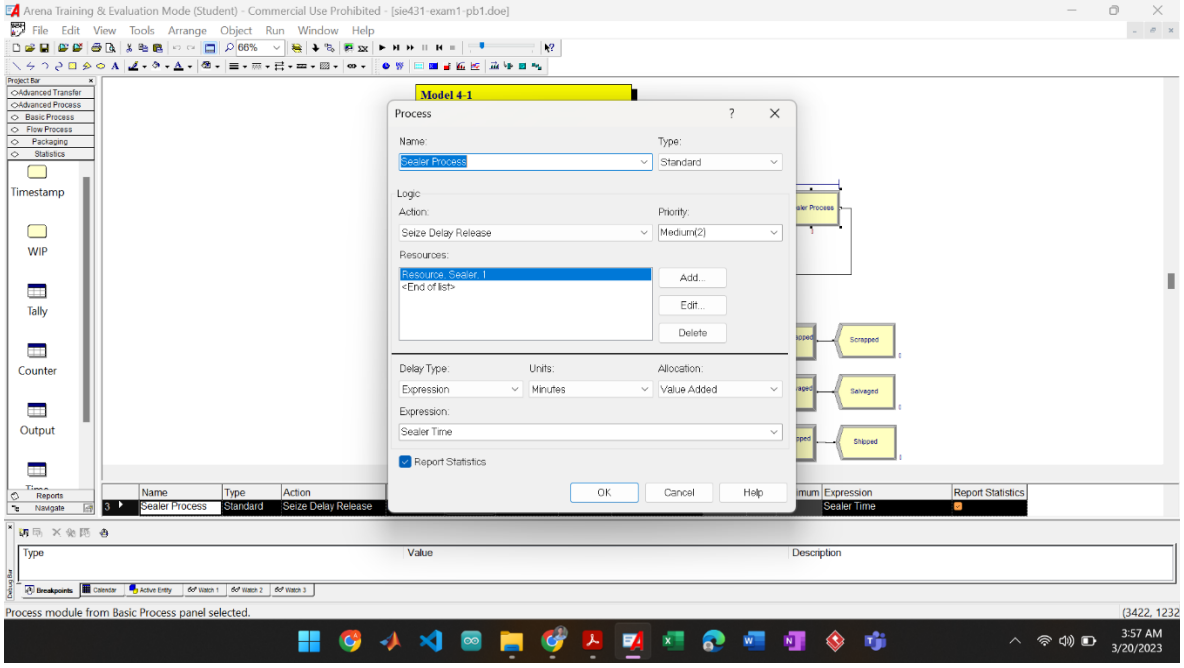
1) A screenshot of the modified model and the parameters inside the modules you have added or modified;

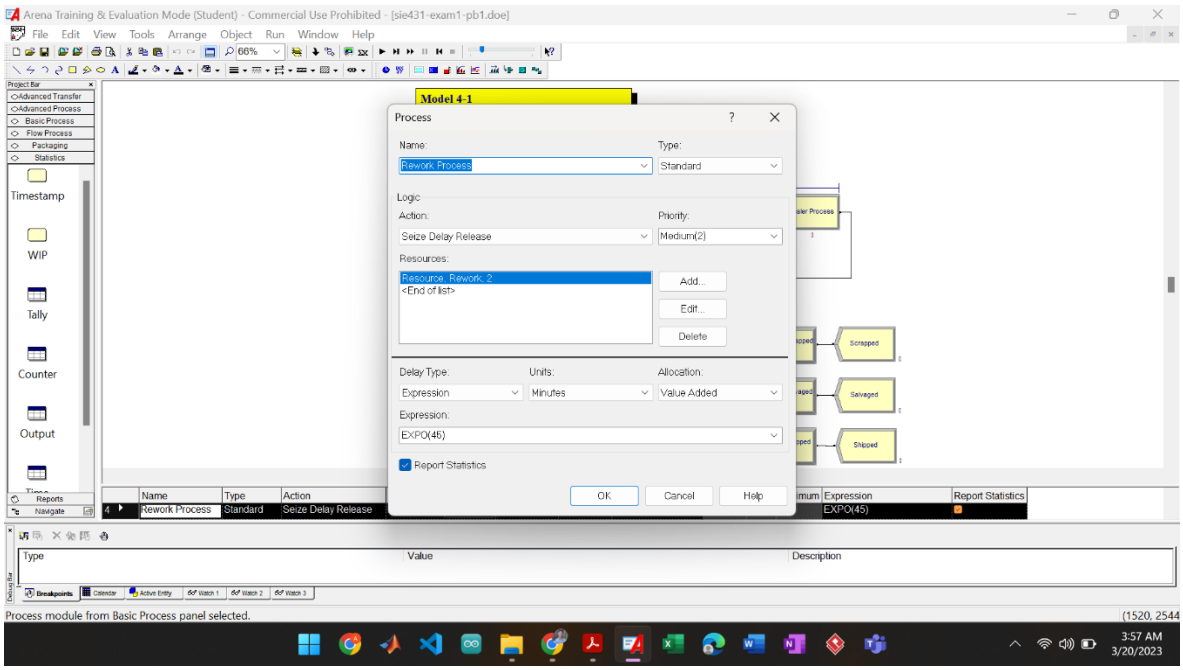



Arena Training & Evaluation Mode (Student) - Commercial Use Prohibited - [sie431-exam1-pb1.doe]
File Edit View Tools Arrange Object Run Window Help
Model 4-1
An Electronic Assembly and Test System
Part A Arrive
Assign Part A Sealer and Arrive Time
Prep A Process
Sealer Process
Record Scrapped Parts
Scrapped
Record Salvaged Parts
Salvaged
Record Shipped Parts
Shipped
Create
Name:
Part C Arrive
Entity Type:
Part C
Time Between Arrivals
Type:
Random (Expo)
Value:
25
Units:
Minutes
Entities per Arrival:
1
Max Arrivals:
Infinite
First Creation:
0.0
OK
Cancel
Help
Timestamp
WIP
Tally
Counter
Output
Reports
Navigate
Name
Entity Type
Type
Value
Units
Entities per Arrival
Max Arrivals
First Creation
Part C Arrive
Part C
Random (Expo)
25
Minutes
1
Infinite
0.0
Type
Value
Description
Create module from Basic Process panel selected.
(559, 1633
3:56 AM
3/20/2023


Arena Training & Evaluation Mode (Student) - Commercial Use Prohibited - [sie431-exam1-pb1.doe]
File Edit View Tools Arrange Object Run Window Help
Model 4-1
An Electronic Assembly and Test System
Part A Arrive
Assign Part A Sealer and Arrive Time
Prep A Process
Record Shipped Parts
Shipped
Assign
Name:
Assign Part C Sealer and Arrive Time
Assignments:
Attribute, Sealer Time, UNIF(3,6)
Attribute, Arrive Time, TNOW
<End of list>
Add...
Edit...
Delete
OK
Cancel
Help
Timestamp
WIP
Tally
Counter
Output
Reports
Navigate
Name
Assignments
Assign Part C Sealer and Arrive Time
2 rows
Type
Value
Description
Assign module from Basic Process panel selected.
(1429, 1748
3:56 AM
3/20/2023


Arena Training & Evaluation Mode (Student) - Commercial Use Prohibited - [sie431-exam1-pb1.doe]
File Edit View Tools Arrange Object Run Window Help
Model 4-1
Process
Name: Prep C Process
Type: Standard
Logic
Action: Seize Delay Release
Priority: Medium(2)
Resources:
Resource, Prep C, 1
<End of list>
Add...
Edit...
Delete
Delay Type: Uniform
Units: Minutes
Allocation: Value Added
Minimum: 1.5
Maximum: 4.5
Report Statistics
OK
Cancel
Help
Timestamp
WIP
Tally
Counter
Output
Scrapped
Salvaged
Shipped
Name Type Action
Prep C Process Standard Seize Delay Release
Expression Report Statistics
Type Value Description
Process module from Basic Process panel selected.
(2450, 1523
3:56 AM
3/20/2023


Arena Training & Evaluation Mode (Student) - Commercial Use Prohibited - [sie431-exam1-pb1.doe]
File Edit View Tools Arrange Object Run Window Help
Model 4-1
Process
Name: Sealer Process
Type: Standard
Logic
Action: Seize Delay Release
Priority: Medium(2)
Resources:
Resource, Sealer, 1
<End of list>
Add...
Edit...
Delete
Delay Type: Expression
Units: Minutes
Allocation: Value Added
Expression: Sealer Time
Report Statistics
OK
Cancel
Help
Timestamp
WIP
Tally
Counter
Output
Scrapped
Salvaged
Shipped
Name Type Action
Sealer Process Standard Seize Delay Release
Expression Report Statistics
Sealer Time
Type Value Description
Process module from Basic Process panel selected.
(3422, 1232
3:57 AM
3/20/2023



2) The utilization of the rework process before and after the change.

Before the change:

- Rework = 0.9495

After the change:

- Rework = 0.00

3) The waiting time in queue for Parts A, B, and C in the sealer operation respectively?

Queue Waiting Time (Average)

- Prep A Process.Queue = 8.11 min
- Prep B Process.Queue = 25.75 min
- Prep C Process.Queue = 0.35 min

4) The total number of parts shipped before and after the change.

Before change:

- Total Number Out = 625
- Part A = 389
- Part B = 236

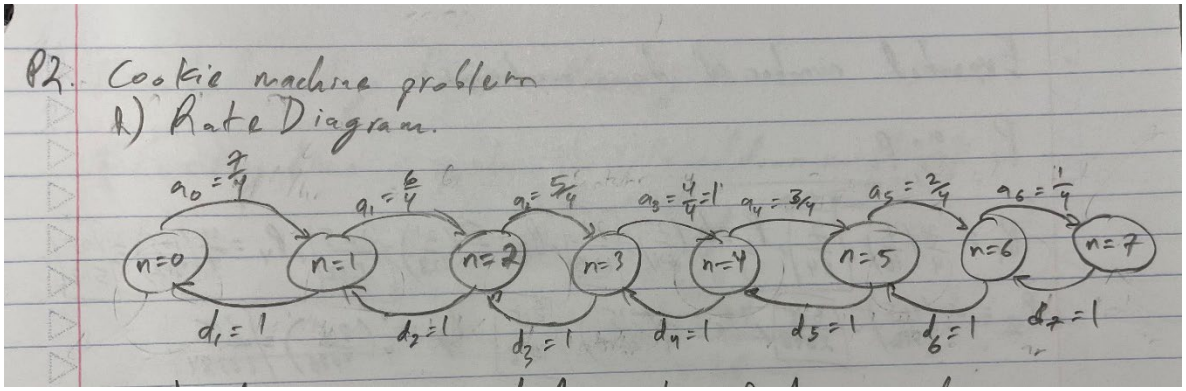
After change:

- Total Number Out = 623
- Part A = 324
- Part B = 222
- Part C = 77

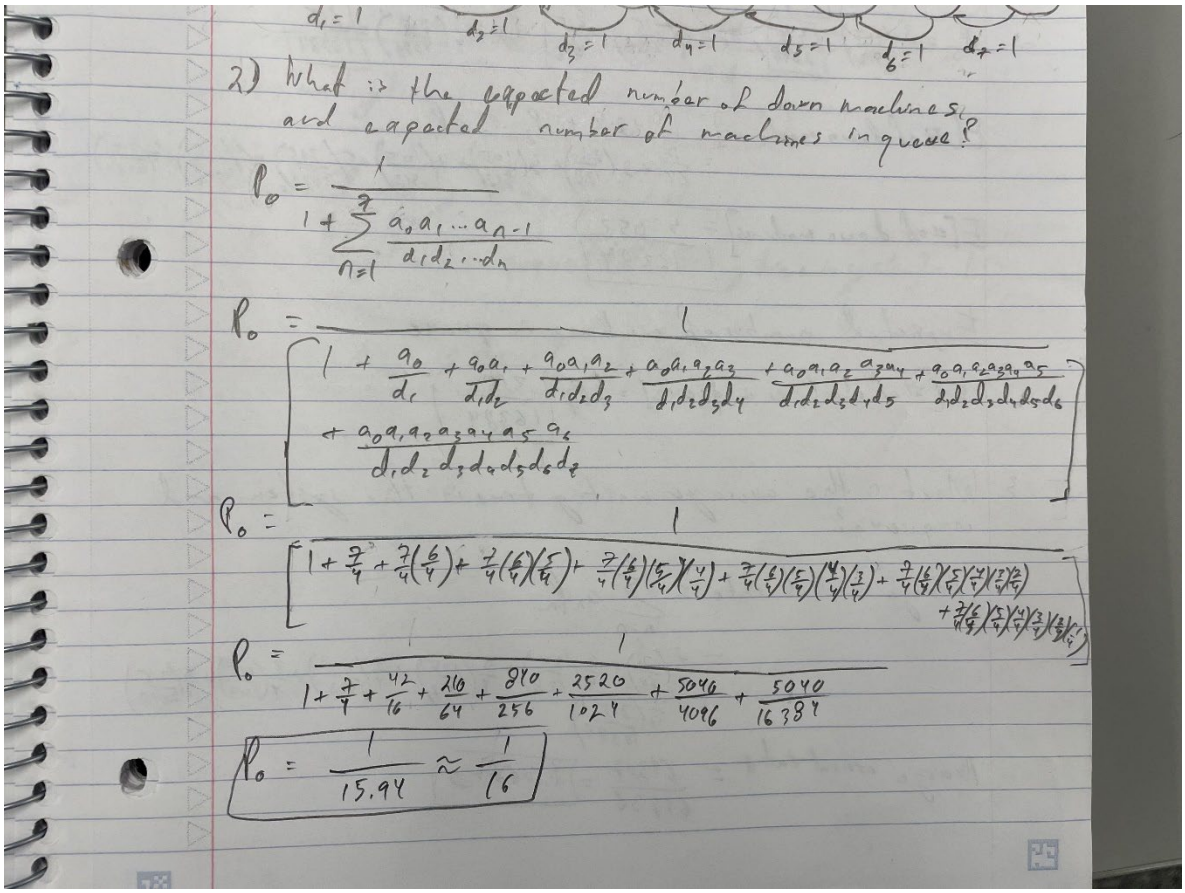
Problem 2 (30 pts):

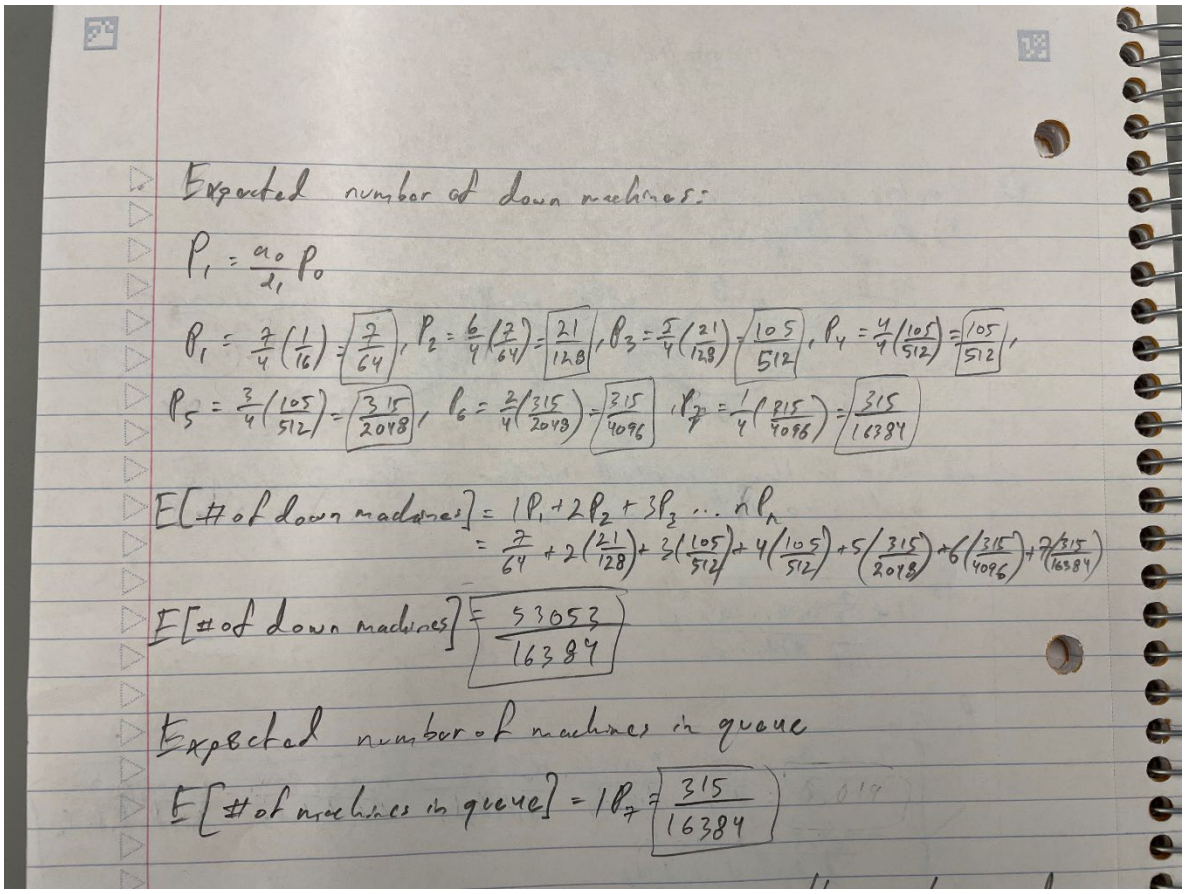
Suppose currently only 1 cookie maker is assigned to 7 machines that must be repaired whenever chocolate gets stuck in the gears. Suppose for each machine the running time before breakdown is known to be exponentially distributed with a mean running time of 4 hours. The service time required by a cookie maker to get the machine running is also exponentially distributed with the mean service time of 1 hour.

1) Draw the rate diagram for the problem.

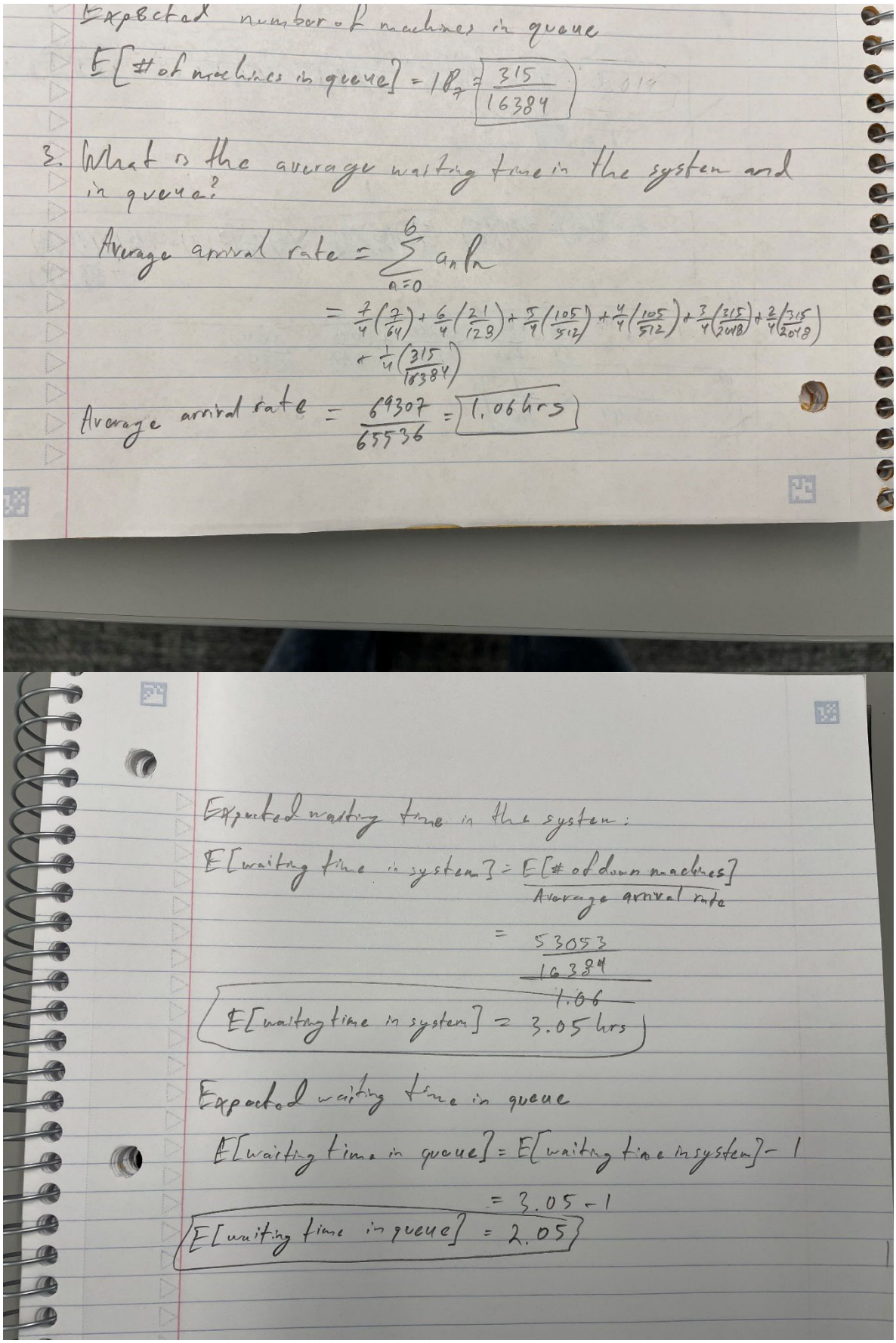


2) What is the expected number of down machines and expected number of machines in queue?





3) What is the average waiting time in the system and in queue?



Expected number of machines in queue

$E[\#\text{ of machines in queue}] = 1P_7 = \frac{315}{16384}$

3. What is the average waiting time in the system and in queue?

Average arrival rate $= \sum_{n=0}^{6} a_n P_n$

$= \frac{7}{4}\left(\frac{7}{64}\right) + \frac{6}{4}\left(\frac{21}{128}\right) + \frac{5}{4}\left(\frac{105}{512}\right) + \frac{4}{4}\left(\frac{105}{512}\right) + \frac{3}{4}\left(\frac{315}{2048}\right) + \frac{2}{4}\left(\frac{315}{2048}\right) + \frac{1}{4}\left(\frac{315}{16384}\right)$

Average arrival rate $= \frac{69307}{65536} = 1.06 \text{ hrs}$

Expected waiting time in the system:

$E[\text{waiting time in system}] = \frac{E[\#\text{ of down machines}]}{\text{Average arrival rate}}$

$= \frac{53053}{16384}$

1.06

$E[\text{waiting time in system}] = 3.05 \text{ hrs}$

Expected waiting time in queue

$E[\text{waiting time in queue}] = E[\text{waiting time in system}] - 1$

$= 3.05 - 1$

$E[\text{waiting time in queue}] = 2.05$

4) What is the server utilization?

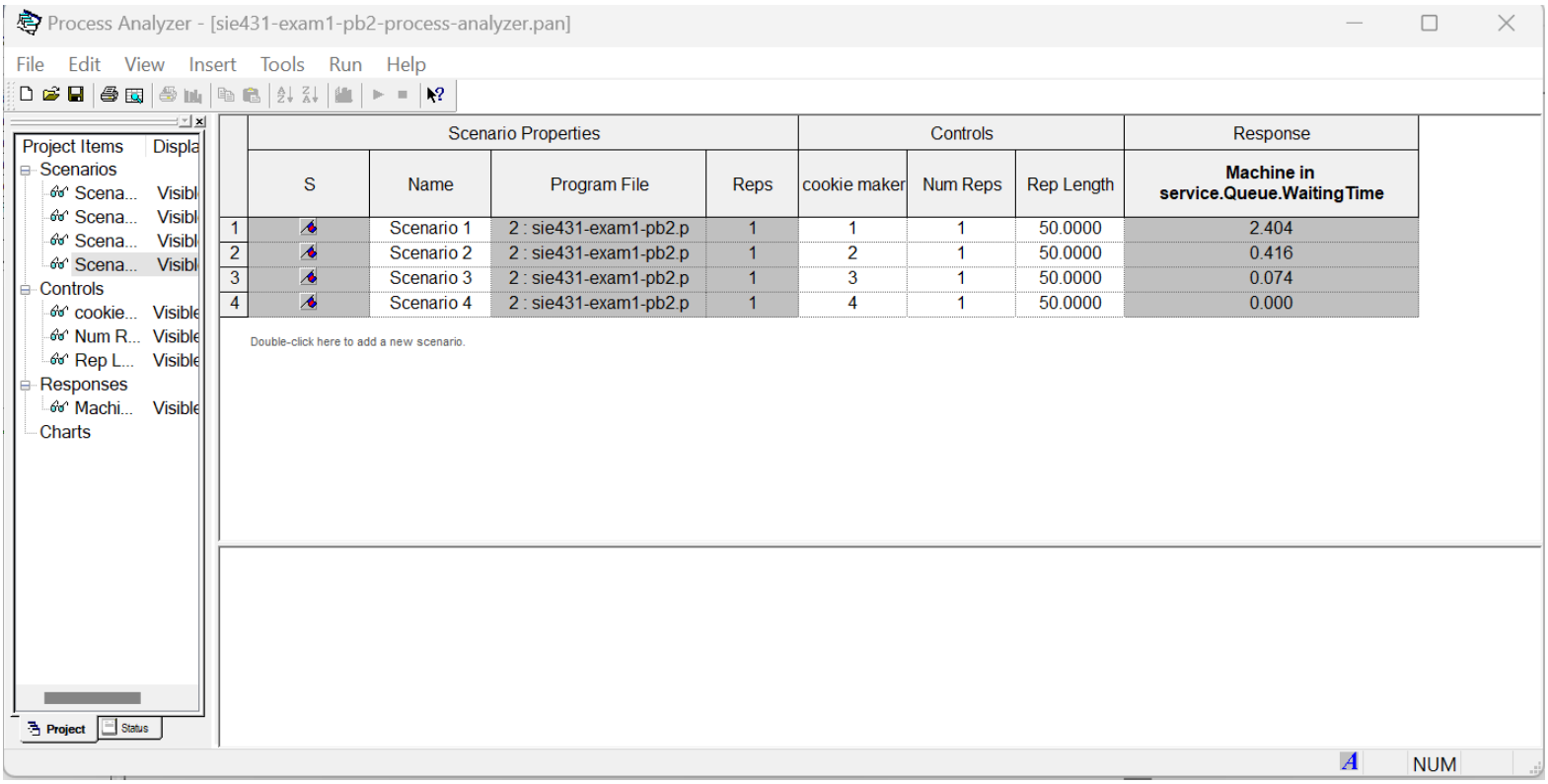
The cookie maker utilization is provided below in the far-right column of the process analyzer table below.

	Scenario Properties				Controls			Responses	
	S	Name	Program File	Reps	cookie maker	Num Reps	Rep Length	Machine in service.Queue.WaitingTime	cookie maker.Utilization
1		Scenario 1	2 : sie431-exam1-pb2.p	1	1	1	50.0000	2.404	0.960
2		Scenario 2	2 : sie431-exam1-pb2.p	1	2	1	50.0000	0.416	0.760
3		Scenario 3	2 : sie431-exam1-pb2.p	1	3	1	50.0000	0.074	0.576
4		Scenario 4	2 : sie431-exam1-pb2.p	1	4	1	50.0000	0.000	0.405

5) Construct an ARENA model for the problem and answer questions 2) – 4). Use the process analyzer to determine the **minimum number of cookie makers required** to serve the 7 machines so that the average wait time in queue will reduce by half. Show the screenshot of the result from the process analyzer.

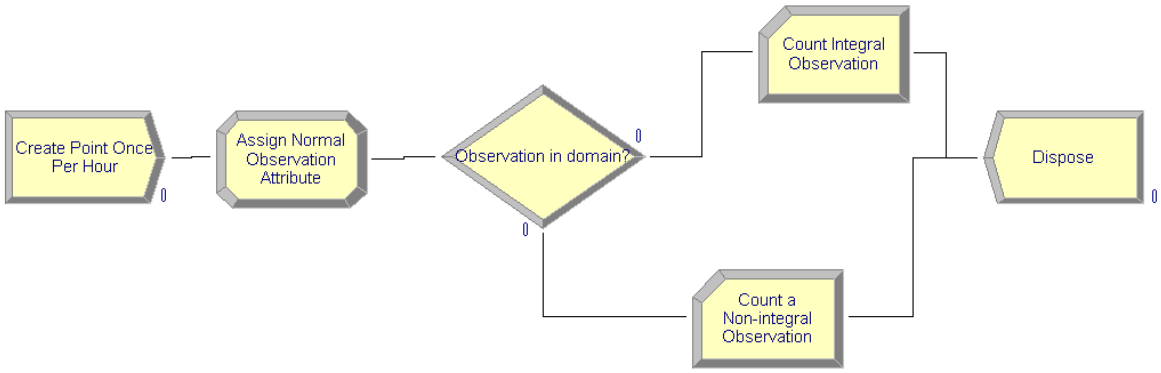
Minimum number of cookie makers required = 2

When the number of cookie makers is 2, the average wait time in queue is reduced from 2.404 to 0.416 (82.7% reduction). For the average wait time to be reduced to exactly half (50% reduction), the cookie maker data type would need to be a real number and not an integer. This, in practice, is not possible as there is no way to have an incomplete human cookie maker working on a machine.



Problem 3 (20 pts): Use Monte Carlo simulation to compute the integral of f(x) = 0.5*sin(x)*cos(x) for x=0 to x=π/4 by modifying book example 4-5. Show the design of your experiment and all the intermediate steps. Show your results by generating 10,000 points, 500,000 points, and 9,000,000 points.

Design



Results

10,000 points:

COUNTERS

Identifier	Count	Limit
Non Integral Observations	78513	Infinite
Integral Observations	21487	Infinite

500,000 points:

COUNTERS

Identifier	Count	Limit
Non Integral Observations	391917	Infinite
Integral Observations	108083	Infinite

9,000,000 points:

COUNTERS

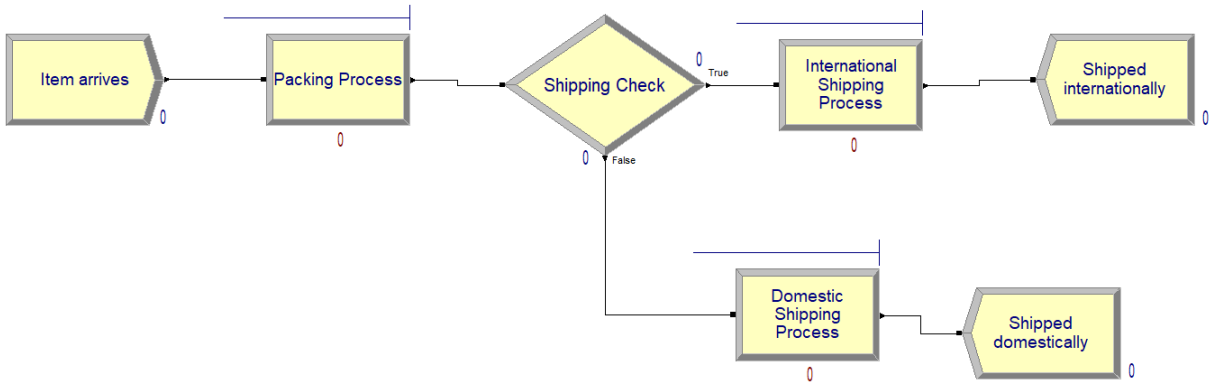
Identifier	Count	Limit
Non Integral Observations	7053543	Infinite
Integral Observations	1946457	Infinite

Problem 4 (30 pts):

Items arrive from an inventory-picking system according to an exponential interarrival distribution with an expected interarrival time of 1.1 (all times are in minutes), with the first arrival at time 0. Upon arrival, the items are packed by one of four identical packers, with a single queue "feeding" all four packers. The packing time is TRIA(2.75, 3.3, 4.0). Packed boxes are then separated by type (each box has an independent probability of 0.2 of being international, and the rest are domestic), and sent to shipping. There is a single shipper for international packages and two shippers for domestic packages with a single queue feeding the two domestic shippers. The international shipping time is TRIA(2.2, 3.3, 4.8), and the domestic shipping time is TRIA(1.7, 2.0, 2.7). This packing system works three 8-hour shifts, 5 days a week. All the packers and shippers are given a 15-minute break 2 hours into their shift, a 30-minute lunch break 4 hours into their shift, and a second 15-minute break 6 hours into their shift; use the Wait Schedule Rule. Run the simulation for 2 weeks (10 replications) to determine the average and the maximum number of items or boxes in each of the three queues.

The average number of items/boxes in the queues for the international and domestic shipping processes were 0, and 0.2042 for the packing process. These values were obtained after setting the item create entity to 100 max arrivals.

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Domestic Shipping Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
International Shipping Process.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Packing Process.Queue	0.2042	0.09	0.06523690	0.4541	0.00	20.0000



The following is the error message obtained when max arrivals were set to the default infinity value.

```
ERROR:

17114:CCREAT
A runtime error was detected at time 1811.9516 at the following block:

 *    1 6$              CREATE,1,MinutesToBaseTime(0.0),Entity 1:
                            MinutesToBaseTime(EXPO(1.1)):
                            NEXT(7$);

Maximum of 150 entities exceeded.
Possible causes:
- A logic problem in your model is creating too many entities or not
  disposing them. The run controller may be helpful in finding the problem.
- You are in demo mode and have exceeded the entity limit. The commercial
  version is required to run large models.
- You have set an entity limit on the DISCRETE element that is too small.
  Remove the limit or set it to a larger number.
- You have exceeded the standard array s
pace for models. Use the Array Sizes
  page in the Run/Setup dialog to increase the RSET space allocated and
  recheck your model.
```