The examination will be four hours long.
There will be eight questions in all. **Students must select 7 out of 8 questions to answer.**
The exam is open book and open notes. The students can bring any relevant written materials.
No computer, iPad, and internet access are allowed.
Calculator is allowed.
Problem 1 (415)

Consider a retailer selling a product. Suppose the annual demand rate is $D$ with a replenishment lead time $L$. Historical sale data shows that the lead time demand approximately follows a UNIFORM distribution within range 0 to some positive value $U$. Given the inventory holding cost $h$, fixed ordering cost $A$, and stock out cost $b$, find the optimal reorder point $r$ and order quantity $Q$.

(a). What is the expression for $U$?

(b). Derive the optimality condition (equilibrium) for $Q,r$.

(c). Solve $Q,r$ in an explicit form, noting that you may need to discuss the range of parameters.

Problem 2. (415)

Adrian is a lead operator at a milling cell that has a 3-axis milling machine and an inspection station. Jobs are released to the milling machine according to a Poisson process at a rate of 6 jobs per hour. Pocketing operations on this milling machine have an exponential distribution with a mean of 5 minutes. Changeover times on the machine take an average of 30 mins with a standard deviation of 10 mins. Adrian runs jobs in batches of ten before carrying out a changeover to another product. After milling the job goes to an automatic inspection station that takes exactly 5 mins for final inspection per part.

a) Determine the throughput and the bottleneck in the cell.

b) Determine the average cycle time (lead time) and WIP in the cell.
Problem 3. (ISyE 510)

(1) The Top Hat Pop Corn Company produces high quality gourmet popcorn that is delivered to independently owned specialty food shops. Popcorn is sold in 2 packages, a 2-ounce package and an 8-ounce package. The sequence of operation is popping corn, packaging it and cartoning the packages. Currently, the weekly demand is 6,000 cartons of 2-ounce bags and 5,000 cartons of 8-ounce packages. (There are 24 2-ounce packages and 12 8-ounce packages per carton). The facility where the popcorn is made is operating on a five-day-a-week, eight hour a day schedule. Currently, this facility has the following equipment and respective capacities. (1 lb = 16 ounces). Please estimate your daily demand and current capacity in terms of pounds/week.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Capacity per Machine</th>
<th>Batch Time</th>
<th>Number of Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Popper</td>
<td>50 lb/batch</td>
<td>6 min</td>
<td>3</td>
</tr>
<tr>
<td>Packaging (2 oz)</td>
<td>40 pkgs/min</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Packaging (8 oz)</td>
<td>20 pkgs/min</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Carton operation (2 oz)</td>
<td>1 min/carton</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Carton operation (8 oz)</td>
<td>1 min/carton</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

a) Determine the capacity utilization of each stage in the process when the daily demand is produced, and identify any bottlenecks that exist.

b) If bottleneck(s) do exist, what are your recommendations for meeting the daily demand?

(2) There are three machines in a cell: Machine A, Machine B, and Machine C. It is known that the concurrent time between the operator and A, B, and C are 2 min, 2.5 min, and 3 min respectively. The independent time of the operator for A, B, and C are 1 min, 1 min, and 1.5 min, respectively. The processing time of A, B, and C are 7 min, 8 min, and 9 min, respectively. Show your steps in the following calculation.

Case 1: Three operators are assigned to the cell. Each operator has been assigned to one machine.

(a) What is the percentage of idle time of each operator?
(b) What is the average production rate per operator?

Case 2: Only one operator is assigned to the cell. The multiple activity chart for one production cycle is given below.
Problem 4 (ISyE 512)

In an $\bar{x}$ chart, the following decision rule applies to a normally distributed quality characteristic with sample size $n=4$:

**Rule:** If at least 2 of the next 3 sample averages plot above the upper 2-sigma limits or at least 2 of the next 3 sample averages plot below the lower 2-sigma limits, conclude that the process is out of control.

(a) What is the type I error probability for this rule?

(b) If the mean of the quality characteristic shifts one and a half process standard deviation (1.5 $\sigma$), and remains there during the collection of the next 3 samples, what is the type II error associated with this rule?

Problem 5. (ISyE 605)

a) How much machining time will be required to reduce the diameter of a cast iron rod from 120 mm to 116 mm over a length of 100 mm by turning using a carbide insert. Assume a cutting speed of 100 m/min and feed of 0.2 mm/rev. Also assume a tool approach distance of 5 mm.

b) Determine the time that will be required to drill a blind hole of diameter 25 mm and depth 40 mm in a mild steel solid block by a HSS drill of 118 degrees cone angle. Assume cutting speed of 25 m/min and feed of 0.16 mm/rev. Also assumed a tool approach distance of 5 mm.

c) Calculate the machining time that will be required to finish a vertical flat surface of length 100 mm by an 8 teeth HSS end mill cutter of 32 mm diameter and 60 mm length in a milling machine. Assume cutting speed 30 m/min, and feed of 0.12 mm/tooth.
Problem 6. (ISyE 615)
Consider a transmission machining line shown in the figure below. The system consists of a main conveyor and seven sub-conveyors connected to the main one. Parts are transported within pallets by the conveyors. Sensors at the intersections identify the type of part on each pallet and the next process it needs to go to control the flow. Parts enter the system at a sub-conveyor. A worker loads the part onto a pallet on the sub-conveyor. The type of part is selected based on daily demands. The loaded part will be transported to the main conveyor if there is an available space. If there is no space, it will stay in the sub-conveyor until it becomes available. Each part should be processed in the order of machining, leak test, pressing, and cleaning machines. For the machining operations, there are two processing routes for type 1 parts. One is to be served at machine $M_3$ and then either of machines $M_1$ or $M_2$. Or, it will be machined at one of machines $M_4$, $M_5$, and $M_6$. Type 2 parts will be served at one of machines $M_7$, $M_8$ and $M_9$. Type 3 parts are served at one of the machines $M_{10}$, $M_{11}$, $M_{12}$, $M_{13}$, $M_{14}$ and $M_{15}$. For leak test, pressing, and cleaning process, all the part types have the same route. That is, a part after the machining process will be served at $M_{16}$ or $M_{17}$, and then $M_{18}$ and $M_{19}$ in serial order. The parts on the main conveyor keep circulating until there is an available buffer of the processing machines. When a part completes a process and if there is an available space on the main conveyor, the part will come back to main conveyor for the next process. If there is no available space on the main conveyor, the part will stay either in the buffer of the last machines or on the sub-conveyor. After all processes is complete, it will be unloaded by a worker at the sub-conveyor and the empty pallet is ready for loading again.

![Diagram of transmission machining line](image-url)
Using the above information, through structural modeling, develop a simplified model for analysis. Explain the rationale and approach for simplification, what type of data to be collected on the factory floor, and the solution procedure of the potential analysis method.
Problem 7 (641)

ABC Inc. makes valves that are used in a variety of industrial applications. The office operations (planning, purchasing etc.) for releasing work orders for valves takes 5 calendar days. Manufacturing work orders are released for a batch of 100 valves and it takes 20 calendar days (from the time they are open till they are closed). Each valve involves manufacturing operations that adds up to 2 hours. The total setup time for a batch of valves is 5 hours. After manufacturing work orders are closed, these valves are put into a finished goods warehouse as stock. ABC Inc has 450 valves in stock on an average and ships roughly 10 valves per day.

a) Define the term Manufacturing Critical-path Time (MCT) and explain the difference between MCT and lead time.

b) Compute the MCT for this valve and the percentage of touch time and non-touch time in the MCT.
(Assume factory operates 24x7x365 and supply chain issues/stocks can be ignored)

c) Using an illustrative example, explain the statement “Traditional measures of supplier quality do not measure suppliers’ capability to make high quality parts – measuring the suppliers MCT gives a better indicator.”

d) Total cost of sourcing parts from a supplier with long MCT could be significantly higher than the quoted price. List four costs that make this total cost of sourcing significantly higher than the quoted price.

Problem 8 (643)

A machine center has two workers. Worker 1 is the more experienced of the two, capable of handling $\mu_1$ jobs per hour; Worker 2 can complete $\mu_2$ jobs per hour, where $\mu_1 > \mu_2$. Jobs arrive according to a Poisson process with rate $\lambda$ per hour. When both workers are idle, the arrangement is that Worker 1 (the more experienced one) will always be the one to serve the next arriving customer.

a. Define an appropriate state space and draw a state transition diagram for the system.

b. Write down the rate balance equations.

c. What is the proportion of time Worker 1 spends serving jobs? (Your answer should be given in a compact form in terms of $\lambda$, $\mu_1$, and $\mu_2$.)