2014 MPS Qualify Exam

- 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 (ISyE 415):

Consider a manufacturing facility that machines a forged product with a demand of \( \lambda \) units per year. Assume that raw forgings for this product are purchased from a supplier with lead time \( L > 0 \) at a cost of \( $c \) per unit. If the ordering costs are \$K \) per order and the holding costs are computed using an interest rate of \( i \% \) per unit-year. Let \( Q_E \) be the economic order quantity that minimizes \( T(Q) \), the sum of holding, ordering and purchase costs for the year.

a. Assume that the manufacturing facility alternatively places orders of size \( Q_1 = 2Q_E \) and \( Q_2 = 0.5Q_E \) respectively during the year. Estimate the value of \( T(Q_1, Q_2) \), the sum of holding, ordering and purchase costs for the year under this new policy. Compute \( T(Q_1, Q_2)/T(Q) \) and comment on your result.

b. If the supplier insists that order quantities must be an integer multiple of some quantity \( Q_{\text{min}} \), and if \( Q_{\text{OPT}} = \alpha Q_{\text{min}} \) is the optimal order quantity under this minimum order constraint, then, prove that

\[
\sqrt{\frac{\alpha - 1}{\alpha}} \leq \frac{Q_E}{Q_{\text{OPT}}} \leq \sqrt{\frac{\alpha + 1}{\alpha}}
\]

c. Also, show that if \( \alpha > 1 \), then the optimum cost \( T(Q_{\text{OPT}}) \leq 1.32 * T(Q_E) \).

List all assumptions clearly.
Problem 2 (ISyE 415)

Consider the traffic lights at an automotive assembly plant shown in Figure 1. The normal sequences for traffic lights are: a green light in one direction, followed by a yellow light, then followed by a similar light pattern in the other direction. It is understood that a green or yellow light in one direction implies a red light in the other direction. Design a PLC to control the light.

(1) Define the outputs of the system
(2) Define the system states
(3) Draw the state transition diagram
(4) Write state equations
(5) Develop ladder logic
Problem 3 (ISyE 510)

The factory has the shape as illustrated below (unit: yards). The existing tool crib is located at (50, 100). A single clerk operates this tool crib. The time required by a clerk to service a customer (i.e., machine operator) has an exponential distribution, with a mean of 2 minutes. Employees arrive at the present tool crib according to Poisson input process at a mean rate of 15 per hour. The employees are uniformly distributed throughout the shop. Employees walk at an average speed of about 5000 yards per hour. To maintain the tool crib, the fixed cost of providing each tool crib is estimated about $20 per hour, plus $25 per hour for the clerk. The labor cost of a customer is $25 per hour.

(1) What is the average round-trip travel time of an employee to the tool crib?

(2) What is the AVERAGE total cost of the tool service per hour? (cost of tool crib, clerk, and customer).
Problem 4 (ISyE 512)

Considering a 2-dimensional statistical monitoring problem. We have a product with two normally distributed quality characteristics. After normalization, the mean and covariance of these two characteristics are \((0, 0)\) and \((1, 0; 0, 1)\). We establish two schemes for the monitoring. Assume the sample size is 1.

(1) Two individual 3-sigma charts, each for one characteristic, respectively. The system is considered in-control if both these two characteristics are in-control.

(2) One Chi-square control chart with a positive control limit of \(A\).

Please answer the following questions:

(a) What is the type I error for Scheme (1)? Please give the detailed steps.

(b) If you are not given the table of Chi square distribution, how to compute the Type I error of scheme (2)? Please give the detailed expression of the type I error and simplify the expression if possible.

(c) If the mean of the process quality characteristics shifted to \((1, 0)\) and the covariance keeps unchanged, what is the Type II error for scheme (1)? Please give detailed steps.

(d) If the mean of the process quality characteristics shifted to \((1, 0)\) and the covariance keeps unchanged, how to compute the Type II error for scheme (2)? Please give the detailed expression of the Type II error and simplify the expression if possible.
Consider a stainless steel (SS300) part that is to be machined on a CNC turning center using a 2” diameter cylindrical workpiece as the raw material. As shown in the drawing, two machined features need to be produced on the part, namely

1. An outer-diameter (OD) turned feature
2. An axial, drilled blind hole

Calculate the total time (in seconds) needed for manufacturing this part.

Clearly show the calculation steps, and list any assumptions that you are making.

Additional information regarding the CNC turning center and the company’s manufacturing practices:

- Maximum main spindle horse power is 12 HP
- Maximum main spindle RPM is 6,000 RPM
- Chip-to-chip tool change time is 3 seconds
- Tool repositioning time (rapid traverse between passes) is 1 second
- Total time for part loading and unloading = 30 seconds
- Clearance distance from the workpiece before starting any cut = 0.05”
- A facing operation (using a facing tool) is always done on the workpiece as the first step before machining of any other features is done. Facing uses same cutting speed and feed as OD turning.
- When producing OD turned features, one finish turning pass is always done following the rough turning. A different tool is used for rough turning and finish turning.
- Axial holes that are less than or equal to 1/8” in diameter are made by first spot drilling (which takes 3 seconds) to achieve a precise start for the drilled hole, followed by drilling using a standard solid-carbide twist drill.
- The Unit Horse Power for machining SS300 is 1.6 HP/in³/minute (Hint: To calculate the HP needed for a machining operation, you need to compute the material removal rate (in³/minute) and multiply it by the Unit horse power needed for that machining operation)

Assume the following machining process parameters:

For the OD turning,

- Recommended cutting speed for rough turning = 500 sfpm (surface feet per minute)
- Recommended feed for rough turning = 0.012 ipr (inches per revolution)
- Maximum depth of cut for rough turning = 0.15”
- Recommended cutting speed for finish turning = 700 sfpm
- Recommended feed for finish turning = 0.006 ipr

For the drilling,

- Recommended cutting speed is 250 sfpm
- Recommended feed for 1/8” dia hole is 0.0025 ipr

NOTE: Figure is not to scale
Problem 6 (ISyE 615)

Consider a two-machine serial line described by geometric reliability model with buffer capacity 2. The failure and repair probabilities of machine $m_i, i=1,2$, are defined by $P_i$ and $R_i$, respectively. Time-dependent failure and block before service are assumed. The first machine is never starved and the last machine is never blocked. To evaluate the production rate, $PR$, of the system, answer the following questions:

1. Define and list all the states of the system
2. List the balance equations
3. Explain a possible way to calculate $PR$
Problem 7 (ISyE 641):

Jay Cutler is the VP of Manufacturing at Packers Inc., a manufacturer of high variety custom hydraulic cylinders. In order to reduce lead times and costs, Jay would like to make the following two policy changes. First, he wants his purchasing manager Mark Tressman to avoid buying raw material bar stock in large quantities from their supplier. Instead, he suggests that Mark should purchase smaller quantities with more frequent deliveries. Second, Jay wants his production supervisor Mike McCarthy to split any customer order that is for larger than 100 cylinders into smaller production orders (incurring additional setups if necessary), even if the customer insists that the entire order be sent in a single shipment. Jay is facing stiff opposition from Mark, Mike and Dom, the VP of Finance regarding these new policies. All three of them think that these new policies will increase costs and lead times, and not reduce them. Jay would like to make a rational case in support of these policies by conducting a fair and balanced cost and benefit analysis corresponding to these two strategies.

a. List down at least four costs that would increase and four costs that would decrease at Packers Inc., if Mark followed the new purchasing policy recommended by Jay. Based on these costs, make the argument that this new purchasing policy would be beneficial to costs and lead times at Packers Inc.

b. List down at least four costs that would increase and four costs that would decrease at Packers Inc., if Mike followed the new production policy recommended by Jay. Based on these costs, make the argument that this new purchasing policy would be beneficial to costs and lead times at Packers Inc.

Note: While listing costs, make sure that you list tangible costs and benefits. Dom, the VP of Finance does not believe that arguments based on opportunity costs are credible.
Problem 8 (ISyE 643)

Consider a machine with two job classes. Jobs of Class 1 are released according to a Poisson process with rate $\lambda_1 = 1/8$ (per minute). The distribution of the processing time of Class 1 job is exponential with rate $\mu_1 = 1$ (per minute). Jobs of Class 2 are also released according to a Poisson process with rate $\lambda_2 = 1/8$ (per minute). The distribution of the processing time of Class 2 job is exponential with rate $\mu_2 = 1/3$ (per minute). Jobs of class 1 have a preemptive priority over the jobs of Class 2 (i.e. jobs of class 2 will be interrupted to process as long as there is a Class 1 job in the system.)

a) What is the expected waiting (queueing) time of a Class 1 job?

b) From queueing theory, it is known that an arbitrary arrival finds, on its arrival at the queue, an amount of work already waiting for the machine that is equal to the expected waiting time of an $M/G/1$ queue with Poisson arrivals at rate $\lambda = \lambda_1 + \lambda_2$, and a service time distribution that is a mixture of two exponentials with rates $\mu_1$ and $\mu_2$ with mixing probabilities of 0.5 and 0.5. Using this result calculate the expected waiting time of a Class 2 job. (If you could not obtain a numerical result, please provide a detailed procedure on how you might be able to derive the result).