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):

An auto manufacturer uses 500 tons of steel per day on a consistent basis. The company pays $1100 per ton of steel purchased, and each order incurs a fixed ordering cost of $2250. The holding cost is $275 per ton of steel per year and the penalty cost for back orders is $5000 per ton per year.

a) Derive an expression for the optimal order quantity, reorder interval, and average cost per year when no backorders are permitted. Calculate the optimal order quantity, reorder interval, and average cost per year for this case.

b) Derive an expression for the optimal order quantity, reorder interval, and average cost per year when backorders are permitted. Calculate the optimal order quantity, reorder interval, and average cost per year for this case.

c) Comment on the difference.

Explain your notation and list all assumptions clearly.
Problem 2 (ISyE 415)
Consider the design of a burglar alarm for a house. When activated, an alarm and lights will be activated to encourage the unwanted guest to leave. This alarm be activated if an unauthorized intruder is detected by window sensor and a motion detector. With any alarm an activate/deactivate switch is also needed. The inputs and output are chosen to be:

A = Alarm and lights switch (1 = on, 0 = off)
W = Window/door sensor (1 = OK, 0 = off/detect)
M = Motion sensor (0 = OK, 1 = off/detect)
S = Alarm activation switch (1 = on, 0 = off)

The basic operation of the alarm can be described as: If window/door sensor is broken (turns off), sound alarm and turn on lights

a) Develop a table to illustrate the input-output relationships
b) Introduce alarm action using Boolean equation
c) Simplify the original Boolean equation
d) Implement the simplified equation using ladder logic diagram
Problem 3 (ISyE 510)

A facility is split into four equal-sized areas labeled as A, B, C, D, respectively, as illustrated in figure 1. The size of each grid in the picture is 1 unit by 1 unit. Each area occupies 4 unit² and their boundaries are marked by the thick lines. We want to layout four departments, labeled as 1, 2, 3, 4, respectively, to these 4 areas. The material flow among these 4 departments are shown in Figure 2. Please answer the following questions:

![Figure 1. Illustration of areas in the facility](image)

![Figure 2. The material flow chart among the 4 departments](image)

(1) The distance between two areas are measured by the rectilinear distance between the corresponding centroid of the areas. Please provide the distance matrix for these 4 areas in Figure 1.

(2) Initially, we assign departments 1, 2, 3, 4 to areas A, B, C, D, respectively. Please use pair-wise exchange method to improve the layout. You only need to do one step pair-wise exchange.

(3) We try to use Hungarian’s method to calculate the low bound of the pair-wise exchange method. To do that, we need a table of lower bound on assignment costs as shown below. What is the value of XX in the table?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>5</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>3</td>
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<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

![Table](image)
(4) Assume the table of lower bound on assignment costs is given as follows (Note: the values in the table are assumed values. They are not calculated based on the previous information provided)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>13</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>13</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>C</td>
<td>14</td>
<td>17</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>D</td>
<td>16</td>
<td>20</td>
<td>30</td>
<td>35</td>
</tr>
</tbody>
</table>

Using this table, what is the lower bound of pair-wise exchange using Hungarian’s method?
Problem 4 (ISyE 512)

Assuming $T^2$ statistic is used to monitor a multivariate normal process. The sample mean and sample variance are estimated based on the sample size equal to 10:

$$
\bar{x} = \begin{bmatrix} 1 \\ 4 \end{bmatrix} \quad \text{and} \quad S = \begin{bmatrix} 2/3 & 1/3 \\ 1/3 & 1/3 \end{bmatrix}.
$$

We would like to test $H_0$:

$$
\mu_0 = \begin{bmatrix} 2 \\ 4 \end{bmatrix}.
$$

(1) What is the value of $T^2$ statistic?

(2) What is the distribution of the $T^2$ in (a)?

(3) What is your conclusion if testing the $H_0$ at $\alpha=0.01$ from (1) and (2)?

(4) Assume that the in-control mean is $\mu^0$ and the in-control covariance matrix is $\Sigma^0$, which has eigenvalues $\{\lambda_1, \lambda_2\} = \{1, 1/3\}$. Let $e_1$ and $e_2$ denote the respective eigenvectors corresponding to $\lambda_1$ and $\lambda_2$, where $e_i^T e_i = 1$ for $i = 1$ and 2. If we have two mean shifts: $\mu_1 = \mu_0 + c e_1$ and $\mu_2 = \mu_0 + c e_2$, where $c$ is some constant number. Which of the two mean shifts has a higher probability of being detected? Please provide detailed steps.
Problem 5 (ISyE 605)

Consider a brass part that is to be machined on a CNC turning center using a 4” diameter cylindrical workpiece as the raw material. As shown in the drawing, a compound hole feature, comprising an unthreaded section (0.5” in diameter) and a threaded section (1.75” in diameter and thread pitch 16 TPI - threads per inch), is to be machined.

**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 that may be relevant for this problem:

- 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 any other feature. You can assume that the facing operation time for this part will take 16 seconds (including tool change time).
- When producing features using boring (ID turning), one finish boring pass is always done following the rough boring operation. A different tool is used for rough boring and finish boring.
- When standard solid-carbide twist drills are used, a spot drilling operation (which takes 5 seconds including tool change time) is done first to achieve a precise start for the drilled hole, followed by drilling using the solid-carbide drill. On the other hand, indexable drills can be used without first doing a spot drilling operation.
Problem 6 (ISyE 615)

Consider a flexible manufacturing system capable of making two different product types. The incoming product types are randomly and uniformly mixed with probability $\alpha_j$ for a type $j$ part, $j=1, 2$. Time is slotted into production cycles. In each cycle, for part type $j$, the system has probability $p_j$ to be able to make one part and $1-p_j$ to be failed to produce. The flexible system needs to enter a setup state if the next product type $j$ is different from the current one. The probability to exit from the setup state is $s_j$. The system would transfer to the corresponding production state after setup. Let $e$ denote the long run efficiency of the system and $e_j$ as the individual efficiency for product type $j$.

(1). Define the system states and draw a state transition diagram.

(2). Derive the formulas to calculate $e$ and $e_j$. 
Problem 7 (ISyE 641):

In a company manufacturing high variety of custom engineered products, lead time reduction efforts should not only focus on internal manufacturing lead times, but also on the lead times for procuring components and parts from suppliers. In this context answer the following questions:

a) “Performance incentives used in purchasing departments lead to behavior that increases lead times as opposed to decreasing it.” Explain why.

b) “Using quality or on-time delivery performance as performance measures for your supplier might be counter-productive.” Explain why.

c) “The total cost of doing business with a supplier with long lead times, far exceeds the piece price paid per unit.” Give eight additional costs that would be incurred to support this statement.
Problem 8 (ISyE 643)

There are two manufacturing systems. The first system has an NC machine with production rate 10 parts/hour and the second has an NC machine with rate 20 parts/hour. The maintenance cost of the first system is 100 dollars per month and that of the second system, 180 dollars per month. The arrival rate of raw parts to both systems is 8 parts/hour. The inventory cost of parts is one dollar per part per hour. Assume 200 working hours per month. Which of the systems is more cost-effective? Why?