1. (7 points) It is 5:00AM and a resident doctor has different orders to complete before the
night shift hand-off time at 6:00AM. There are 3 types of orders: lab order, pharmacy order,
and discharge order. Lab orders have priority over all patients’ orders because waiting times
can be long. For each particular patient, all lab and pharmacy orders should be entered before
a discharge order. The orders (per patient) and the resident’s estimation (in minutes) for their
duration are given in the table below:

<table>
<thead>
<tr>
<th>Patient</th>
<th>Lab order</th>
<th>Pharmacy order</th>
<th>Discharge order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>None</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Patient 2</td>
<td>None</td>
<td>None</td>
<td>15</td>
</tr>
<tr>
<td>Patient 3</td>
<td>15</td>
<td>10</td>
<td>None</td>
</tr>
</tbody>
</table>

a. (2 points) Draw the precedence constraints as a network, where each order represents
a node, and the arcs represent the precedence constraints. Label each node with the
patient number {1,2,3} and the type of order {L,P,D}; e.g, 3-L= patient 3, lab order.
b. (4 points) Use Lawler’s algorithm to schedule the orders. What is the tardiness for
each of the orders?
c. (1 points) The resident doctor would like to minimize the maximum tardiness of these
orders. Could he use your solution in b)? Why?

2. (3 points) Consider a set of n jobs that have to be processed first on machine 1 and then on
machine 2. Answer and explain:
   a. (1 point) If we want to minimize the elapsed time between the initiation of the first
   job and the completion of last job, then the sequence of jobs processed in machine 2
   should be the same as the sequence of jobs processed on machine 1. True or False.
   b. (1 point) If we want to minimize the total flow time, then there exist an optimal
   solution where there is no idle time between the jobs on machine 1. True or False.
   c. (1 point) The processing times of job i are 2 hours and 4 hours on machine 1 and
   machine 2, respectively. The processing times of job j are 1 hour and 2 hours on
   machine 1 and machine 2, respectively. If we want to minimize the makespan, then
   job i must precede job j. True or False.

To answer the following questions you should have read: warehousing lecture notes and
handouts; and chapters 1, 2, 4, 5 from Bartholdi and Hackman book “Warehouse and
Distribution Science” (link available on the course webpage).

3. (5 points) A warehouse holds approximately 745 pallets of inventory of Product X. Every
week there are three full trucks arriving from the supplier to the warehouse. The capacity of
each truck is of 48 pallets. On average, what is the number of inventory turns per year of
Product X?
4. **(10 points)** Answer briefly the following:
   a. **(1 point)** A third-party warehousing company charges its customer by the number of pallets moved from inbound trucks and to outbound trucks. If this company wants to implement a warehousing management system (WMS), what would be the minimum functionalities they would require?
   b. **(1 point)** The manager of a warehouse observes that his workers, especially the recently hired, waste too much time looking for products. What functionality of a WMS would likely help the most in this situation?
   c. **(1 point)** Static shelving is commonly used as a storage mode for fast, high-volume picking SKUs. True or False. Explain.
   d. **(1 point)** In a double-deep rack, every pallet is independently accessible. True or False. Explain.
   e. **(1 point)** Mention one advantage and one disadvantage of warehouse automation.
   f. **(1 point)** An ABC analysis will likely show that most of the SKUs in the warehouse represent a very small fraction of the volume. True or False. Explain.
   g. **(1 point)** From the four main warehouse processes: receiving, put-away, picking, and check-pack-ship, which is more labor intensive?
   h. **(1 point)** What are the tradeoffs when designing a fast-pick (forward picking) area?
   i. **(1 points)** Workers at a warehouse observe that some shelves in the fast-pick area are restocked relatively less frequently. We can conclude that the SKUs in these shelves require more space in the area. True or False. Explain.
   j. **(1 point)** Suppose you allocate equal space to all SKUs in a fast-pick area. If you triple the number of SKUs in the area, then the total number of restocks will triple as well. True or False. Explain.

5. **(5 points)** Sort the following SKU list from the highest to the lowest claim to storage in a forward pick area. Hint: You first need to compute the case volume for each SKU and then obtain the ft³ per unit, in order to compute the flow per SKU in ft³ per day.

<table>
<thead>
<tr>
<th>SKU</th>
<th>Case dimensions (ft)</th>
<th>Units/case</th>
<th>Units sold/day</th>
<th>Picks/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wide</td>
<td>Length</td>
<td>Height</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

6. **(10 points)** Assume that all four SKUs above were chosen for the forward picking area. What percentage of the total available volume should be allocated to each of them given:
   a. **(2 points)** Equal space allocation
   b. **(4 points)** Equal time allocation
   c. **(4 points)** Optimal allocation

7. **(5 points)** Assume that the available volume in the forward picking area is 10,000 ft³, the saving per pick is $0.1, and the restocking cost is $0.35.
a. (4 points) Given the optimal volume allocation in 6. c), what is the benefit of having each SKU in the forward pick area?
b. (1 point) Explain what you would do to make sure that the four (and no fewer) SKUs should be included in the forward picking area. (No need to calculate)