Answer the following questions:

**Question 1:**

i. To select or design a coding system, there are several requirements that should be taken into consideration. What are these requirements?

ii. What is cellular manufacturing?

iii. How to determine the similarity coefficient between pairs of machines?

iv. What are the differences between a rough plan and a detailed plan in process planning?

v. Specify four types of robot reach and their related configurations.

vi. Develop the form code (first five digits) in the Opitz coding system for the parts illustrated in Figures 1 and 2 (dimensions are in millimeters).

**Question 2:**

i) In a turning operation, compute the cycle time, the production rate, and the percent utilization of machine and robot for single-machine robotic cell for 8-h shift if the system availability is 95%. The length of the part is 15 in., the diameter of the raw material is 3 in., and the diameter of the finished part is 2.9 in. The overtravel of the cut is 0.5 in. The recommended feed rate is 0.1 ipr. The time for a cutter change is 3 min. The tool life can be expressed as: \( v \cdot t^{0.26} = 600 \). Use minimum production cost criterion. Assume the operator rate is SR60/h and the machine rate is SR45/h. The cutter costs SR30 each. Ignore the batch size and the batch setup cost, and costs related to robot operations

The other robot operations times are:

- Robot picks up a part from the conveyor: 4.0 s
- Robot moves the part to the machine: 1.4 s
- Robot loads the part onto the machine: 1.0 s
- Robot unloads the part from the machine: 0.6 s
- Robot moves to conveyor: 1.6 s
- Robot puts the part on the outgoing conveyor: 0.4 s
- Robot moves from the output conveyor to the input conveyor: 3.0 s

ii) Illustrate the improvement in productivity with the use of minimum production time criterion.

iii) Solve (ii) using double-handed grippers and compare your results.
**Question 3:**

The following table lists the S-codes and routings of ten parts that are being considered for cellular manufacturing in a machine shop. Parts are identified by letters, and machines are identified numerically.

<table>
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<tbody>
<tr>
<td>A</td>
<td>7514</td>
<td>M3→M2→M7</td>
<td>F</td>
<td>1110</td>
<td>M5→M1</td>
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<tr>
<td>B</td>
<td>1010</td>
<td>6M→M1</td>
<td>G</td>
<td>6504</td>
<td>M3→M2→M4</td>
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<td>C</td>
<td>2020</td>
<td>M6→M5</td>
<td>H</td>
<td>7504</td>
<td>M3→M2→M4→M7</td>
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<tr>
<td>D</td>
<td>1130</td>
<td>M6→M5→M1</td>
<td>I</td>
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<td>E</td>
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<td>M3→M2→M7→M4</td>
<td>J</td>
<td>1130</td>
<td>M5→M6→M1</td>
</tr>
</tbody>
</table>

For the data given:

a) Develop the part-machine incidence matrix

b) Apply SLCA technique to the part-machine incidence matrix to identify two logical part families.

c) Determine the standard process plan for each part family.

d) Use the given part codes to construct family matrices.

e) Use the constructed family matrix to find the standard process plans for the following parts:

1. 1021
2. 1130
3. 6554
4. 7124

**Question 4:**

The joints and links of the TRLR robot have the following values: \( \theta_1 = 0^\circ, \theta_2 = 45^\circ, \lambda_3 = 400 \) mm, \( \theta_4 = 30^\circ, L_0 = 0, L_1 = 500 \) mm, and \( L_4 = 20 \) mm.

i. Draw a simple diagram for this robot.

ii. Determine the values of x, y, and z in the world space coordinate.